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PAGET'S NEW WARP WEAVING AND KNITTING MACHINE.

PROBABLY in the whole range of the mechanical division of the Paris exhibition there is not to be found a more ingenious and remarkable novelty than this extraordinary production. It was made the subject of a recent paper read before the Institution of Mechanical Engineers, in session in Paris, by its designer, Mr. Arthur Paget, Loughborough.

In making textile fabrics, three methods may be employed. The best known of these is that of ordinary weaving, with a warp running longitudinally through the fabric, and a weft crossing it transversely. Another method is that of knitting, in which one thread is interlaced, so as to form the fabric by a series of loops. In certain cases a number of threads are simultaneously used in knitting, and these form weft threads interlaced across the fabric without warp threads running longitudinally. The third method of making fabrics is that of warp weaving, in which no weft threads are used, and the fabric is produced by the interlacing of a number of warp threads running longitudinally. It is this method of weaving which, by Mr. Paget's machine, has been brought to its highest state of perfection. In ordinary woven fabrics the width is the same throughout the length of the piece, and hitherto the only method known of producing shaped fabrics—that is, fabrics in which the width varied—has been by knitting; but with the author's new loom the fabric is shaped or finished in the process of warp weaving by a very ingenious device, which automatically alters the length of the loops as they are formed.

In this machine the longitudinal threads (1,008 in number) are interlaced by the action of three principal parts, which are technically termed the troughs, the needles, and the hooks. A set of these three parts is requisite for every thread, and at least one additional needle. Thus if the loom is weaving 1,008 threads, then there will be required 1,008 troughs, 1,009 needles, and 1,008 hooks. The threads are wound upon a weaver's beam in the usual manner of preparing a warp for an ordinary loom; but in some cases the threads may be taken direct from the cops, spools, cones, or bobbins on which the yarn is delivered by the spinner.

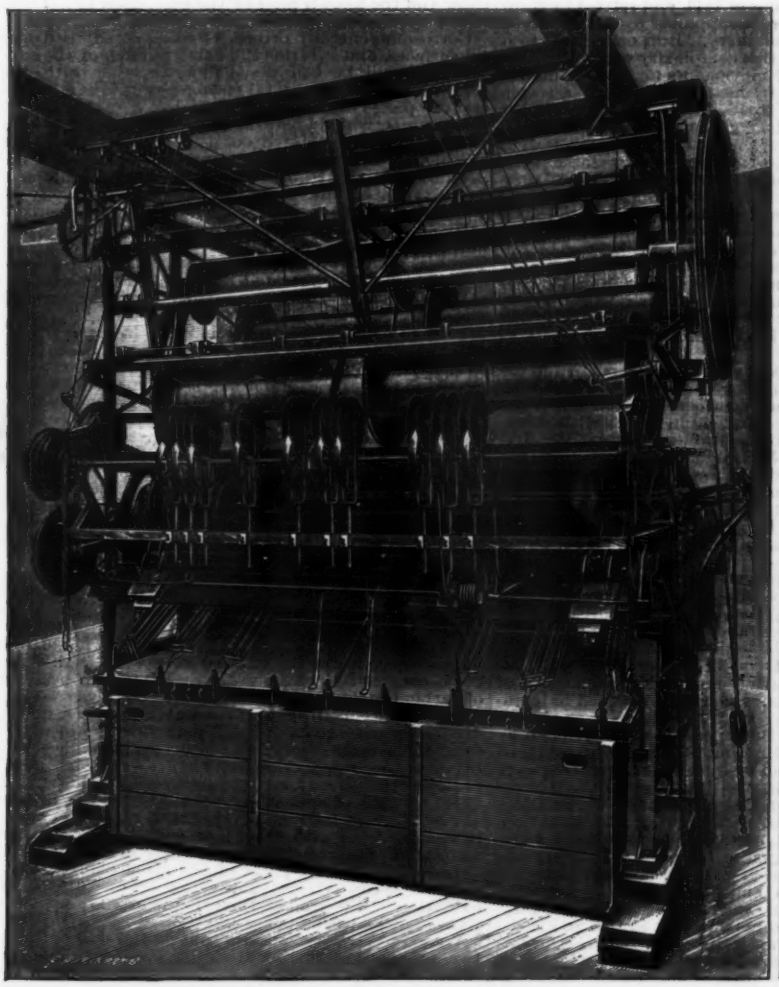
The troughs are fastened side by side to a horizontal bar, about 12 to the inch, although this number may be varied according to the quality of thread employed and fabrics to be produced. Below the troughs, and with a certain inclination to the horizontal, is the row of needles, which have a longitudinal movement. Each trough when at rest is equidistant between the stems of the needles on each side of it, and its lower opening or lip is placed so as to just clear the stems of the needles when it is moved sideways. In this movement each thread will be laid across the stem of one needle. The needles then move backward so far that the point or beard of each needle passes over the thread, after which the beard of the needle is pressed into a cavity in its stem—technically known as the eye—in order that the point may pass through the loop of the fabric previously formed, which loops are on the stems of the needles and in front of the hooks. The backward motion of the needles continues, so that the heads pass a certain distance beyond the front of the row of hooks, and a certain length of thread is pulled by each needle against the face of each hook, and through each trough from the beam of warp, through the loop of the fabric which was on the stems of the needles, and which is drawn over the heads of the needles by the hooks.

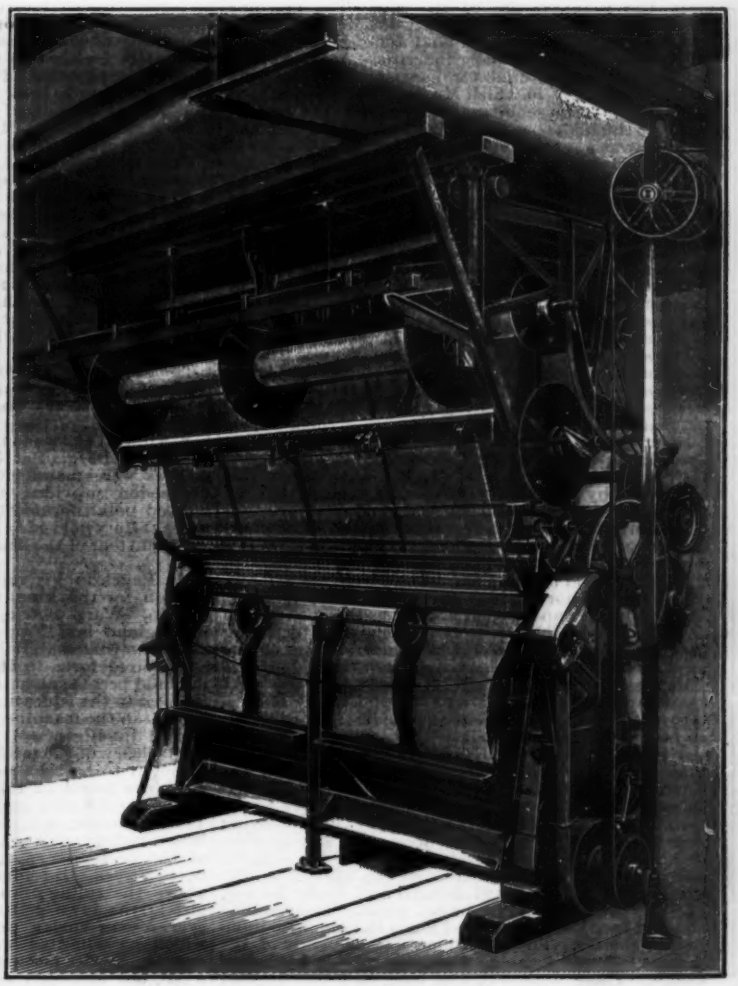
While the heads of the needles are behind the troughs, the latter are again moved sideways into their former position. The hooks are then made to descend so that the under side of the point at the top of each hook just presses on each thread when the needles are made to advance, and the hooks to descend simultaneously, so that the loops already pulled by the needles are held down by the hooks while the row of needles advances into their former position. This completes the cycle of one operation, and after the row of troughs has been made to move one needle to the left, so as to lay the threads over the contiguous needles, it is made to move again in the same direction one needle further, before the needles again come forward to receive a fresh row of loops. Each thread is thus passed under the needle next to the left of that on which the last loop was formed, and the separate chains are thus interwoven. Before the needles again come forward to receive a fresh row of loops the row of troughs is moved to the right, and each thread is passed under the needle upon which the first loop was made, ready to form a loop upon it again. Thus each thread forms a loop alternately on neighboring needles, and a cloth or woven fabric is produced.

To vary the closeness of the weaving, the distance to which the row of needles and row of hooks retire is varied. In this manner, longer or shorter loops are pulled by the needles and held by the hooks, and it is a peculiar property of warp-woven fabrics that, with an alteration in the length of the loops, there is produced a corresponding alteration in the width of the piece. Taking advantage of this property, the author is able to shape the fabrics while they are being woven, by the simple process of lengthening or shortening the loops pulled by the needles.

It would be impossible, without the aid of very elaborate diagrams, to clearly explain the numerous and very ingenious mechanical details by which the various actions of this loom are produced. To facilitate the understanding of his loom, the author showed a model made to a scale many times full size, and the actual loom was shown in operation in the machinery hall at the exhibition. The number of different articles which can be produced on this machine is truly astonishing. It will weave from a lady's cloud, which might be drawn double through an ordinary ring, to a vest, or even a heavy towel with a fringe, the fringe itself being also produced automatically.

Before the discussion on this paper was commenced, the author showed a variety of goods made on his loom, and pointed out that the closeness of the weaving was not altered by the lengthening or shortening of the loops, whereas the width of the piece was thereby altered. It was, moreover, possible to weave certain parts with longer loops and the rest of the fabric with loops of the usual length, thereby producing the fuller appearance necessary for certain articles of under clothing. In the ordinary knitting loom, the loops cannot get over the needle heads if the weaving is too close, but in his new improved loom this difficulty does not exist, and the weaving may be as close or as open as required. An addition had been made to his loom for producing fabrics in different colors with zigzag stripes, which is effected by increasing the number of lateral motions of the trough bar. The usual speed of the machine is 120 loops per minute, which is from seven to ten times more than with the ordinary knitting machine. To show that the machine is capable of weaving very open fabrics, the author exhibited a lady's cloud which, when doubled, could be drawn through a ring, and it has been found possible to weave five such clouds in the width of the machine in





THE PAGET WARP WEAVER AND KNITTER AT THE PARIS EXHIBITION.

2½ minutes, giving an average speed of a cloud in thirty seconds.

The foregoing is from *Industries*. The following additional particulars, together with our illustrations, are from *Engineering*:

During the reading of the paper the action of the machine was made very plain to the audience by means of an excellent moving model, constructed thirty-two times the full size, and so arranged that each of the steps forming the stitches could be clearly seen. By means of this model a piece of bell rope, which represented the fine yarn that would actually be used, was woven or knitted into a small piece of fabric. In addition to this large model, Mr. Paget had also prepared for distribution to the members a number of cards having printed on them a section of the portion of the machine at which the stitch is formed, each card, moreover, having mounted on it in proper position specimens of the actual needles, etc., used. These cards were of much service in making the whole matter clear. To the ordinary engineer or mechanic who has no special knowledge of such subjects, there is, perhaps, no more difficult task than the grasping of the design of textile machinery. The details themselves taken individually may be simple, but they are so multitudinous, and so interdependent on each other, that it is difficult to take a comprehensive view of the whole scheme. In Mr. Paget's warp weaver, however, the whole arrangement is so well worked out, and each part performs its function in so perfect a manner, that once the method of working is seen and explained it is not at all difficult to master the whole mechanism. At the conclusion of the reading of the paper some very beautiful examples of the articles made by the machine were shown.

The first speaker was Mr. B. A. Dobson, of Bolton, who said he had examined the machine in great detail, and was full of admiration for the masterly way in which the author had designed it to so perfectly meet the requirements of the case. The machine worked admirably in every way, but beyond all in speed. If he could have found a defect, he should have thought it a fair matter for criticism, and it would have given him material for discussion, but the truly scientific manner in which Mr. Paget had carried out the design left no room for questioning. He had referred to the high speed at which the machine worked, and this was not so much a matter for wonder in itself as the fact that it was associated with such smoothness of running. It was astonishing that there was no vibration. Certainly he had never seen any machine of a similar description with less of this objectionable feature, and it was a valuable lesson to all engaged in the manufacture of that class of machinery. One of the most interesting points was the remarkable celerity with which the changes were made in the character of the materials produced. The mechanism to effect this was described in the paper, and constituted one of the most novel and valuable features in the design. The old type of knitting machines do not possess this device, but still they have been largely employed. They are mostly constructed, Mr. Dobson went on to say, in Germany. They are beautifully made, and everything that can be done has been done to bring them to perfection. They cannot, however, by any possibility, rival the present machine in speed, for it was beyond their nature to do so. Mr. Paget had obtained his high speed by an entirely different principle, and by the small range of movement he had adopted he could always work from six to ten times faster than an ordinary knitting machine. The shaping device was a most beautiful application of mechanism. There were six motions, and many of the actions were not explained by the author; indeed, the speaker considered it would take six papers, each as long as the one read, to describe them all. Mr. Dobson concluded by saying that he considered Mr. Paget's machine one of the most remarkable inventions of modern times.

Professor Alexander B. W. Kennedy was the next speaker. He said he had had an opportunity of carefully examining this machine, and had seen it at work. In fact, he had spent two days in its company, and the conclusion he had come to at the end of that time was that no man could say his mechanical education was complete until he had mastered the details of this machine. He had seen a row of needles, twelve to the inch, the machine being 84 in. wide, first weaving heavy towels. These towels were made side by side, and were finished in 15¼ minutes, which was equal to about twelve towels an hour, or one every five minutes, fully completed and fringed and ready for use, except that they had to be cut apart. The machine stopped by itself when it had made the requisite number of courses. Then, without any changing of the parts, the same machine wove side by side five ladies' clouds. These were 6 ft. 6 in. long, and were finished in three minutes, which was equal to 100 per hour. The toweling was 67 courses to the inch, and the clouds 2¼ courses to the inch, yet the same machine produced these two very fabrics so very unlike in appearance. The stitch was the same, the only difference being in its length, and the change was effected by the attendant simply pulling a lever. The speaker had a piece of material in which the open cloud pattern had been woven on to the toweling, the one appearing as a border to the other. A point that was of the greatest value in this machine was the ease with which the beams were changed. In a machine working so rapidly as that under consideration, the time occupied in changing the beams and rethreading the machine, were these operations done in the ordinary way, would make a very serious reduction in the percentage of work turned out. Mr. Paget had, however, devised an apparatus by means of which the mechanical labor was very much lessened. He had succeeded in reducing the time necessary for rethreading to as many minutes as it formerly took hours. The whole operation of changing the beams, etc., was carried out by the girl who attended the machine, and one young girl besides, with the assistance of a third girl from a neighboring machine for less than a minute. The taking out of the two old beams and the putting in of the two new ones occupied 8½ minutes. The utmost exertion was the very light pull on the rope of a hoisting gear, which forms part of the machine. The putting of the whole 504 threads of one beam into their respective troughs or guides took exactly ten seconds, and the adjusting of the four or five which not quite accurately entered the troughs brought this up to one minute. From the time when the trapped thread ends were brought to the front of the machine until the whole 1,008 of them had been properly placed, secured by two courses, worked by hand, and the traps cut off, was not more than 3½ minutes. Threads had then to be taken out at intervals to space the machine into five breadths, and new selvedge and mending bobbins had to be put on to suit the new yarn; but with all this and all other delays, including overhauling of the needles, the whole time taken by the change, until the machine started by power on the new work, was exactly 25 minutes. The speaker also wished to call attention to the reservoir beam which gave regular rotation to the main beam. The speed at which the thread was woven varied considerably, but by means of the ingenious device Mr. Paget had employed the rotative action was steady. In conclusion, the speaker remarked that Mr. Paget had said that the machine was absurdly simple; it might be so, but it was to be wished that there were many more engineers who were capable of devising these absurdly simple devices, which were so beautiful in their results.

A speaker here asked if the same machine could be used for fine yarns or threads as well as those of a coarse kind. To this Mr. Paget replied that this was so; in fact, an enthusiastic friend of his had stated his belief that all materials, even as fine as a silk handkerchief, would eventually be made on this machine. Mr. Paget was not sufficiently sanguine to indorse this view, but doubtless a good deal would be done in the manufacture of fine material as experience advanced.

Mr. Daniel Adamson spoke of the excellence of the material produced and the hygienic character of the woven woolen materials when worn as underclothing. He also spoke at some length on the improvement in the mental and moral characteristics that were likely to follow from female attendants having the charge of such a well designed piece of mechanism. With regard to the apparent complexity of the warp weaver at first sight, Mr. Adamson remarked that when he first gave up locomotive engineering in 1849, and settled in Manchester, he was more or less appalled by the apparent complexity of cotton machinery. But, on looking into the matter, he saw that this complexity was due chiefly to the reduplication of movements for a vast number of spindles, and that it disappeared when a single spindle was considered by itself. In the same way, if those who examined Mr. Paget's warp weaver at the exhibition would ignore the fact of its working with 1,008 threads, and make themselves acquainted with the manner in which a single thread did its work, they would find the machine very easy to understand.

Mr. Birckel also spoke of the beauty of design in the machine. He pointed out that the control of motion to one-fiftieth part of an inch was a thing not before effected in any textile machine, and its accomplishment in the case under discussion placed Mr. Paget in the foremost rank of mechanical workers. The spinning mule was a monument of mechanical ingenuity, but even that did not work to such a degree of nicety as this.

The president, Mr. Cochrane, also wished to add his testimony to the extreme ingenuity of the apparatus. A point that struck him was the manner in which the design got rid of the solid metal in the knocking-over bar, while at the same time attaining extreme rigidity. He would be glad if Mr. Paget would say how the needles were manufactured, and especially how the depression provided to receive the turned-over or hooked point, formed by the beard of the needle, was made. He would also like to ask what would be the wear and tear of the machine, that is, how long it would last.

Mr. Paget, in his reply, wished first to thank Mr. Dobson for the kind words of appreciation he had spoken. Warp weaving had been practically dormant in England and France, and almost so in Germany, but now that materials could be shaped so as to take any desired form, to fit the figure, etc., he hoped that it would become an active industry. Mr. Adamson had referred to the education which a girl received in learning to run the machine. With this the speaker agreed, for the intelligence of the operator was developed by the delicacy of the mechanism. He had been told that he ought to be ashamed of himself for inventing such machines as would take the bread out of the mouths of poor girls who earned some money by knitting. This, however, was not his view of the situation. When he first went to Loughborough in 1854 the wages of the best girls engaged in the hosiery industry was 8s. per week. He himself paid 8s. 6d., but that was above the ruling price and there was only one other girl in the town getting such pay. The wages, however, rose in such a proportion that in 1885 and 1886—which he admitted was a time of inflation—the rate was 18s. to 20s. per week. Since then there had been a fall, but although at present times were exceptionally dull, no good hands could be got under 15s. to 16s. per week. Thus by reason of machinery of a type similar to that under discussion, the wages of girls had been raised 100 per cent. even in dull times. Mr. Birckel had made reference to the accuracy to which they had to work, and had mentioned the fiftieth part of an inch as the amount to which the movement had to be controlled. The accuracy of movement, however, had really to be insured within an error of 0·01 in. in either direction, making a total extreme range of $\frac{1}{25}$ in. The essence of good working in machines of this class was extreme accuracy in their manufacture, and he had in constant use at his factory, as an ordinary workshop tool, one of Whitworth's measuring machines capable of measuring to 0·0001 in. Moreover, every man and boy in his works had to learn to measure to half this fraction, and he found practically that there was no difficulty in accustoming the workmen to such accuracy of measurement.

He had been asked a question as to the rigidity and mode of support of the knocking-over bar. A former president of the Institution had once informed him that some cylinders he had bored in a vertical position were no longer circular, but became oval when they were laid on their sides. If that was the case with a comparatively rigid section, such as that of a cylinder, how much more so would it be in a long bar, were it only supported at its extreme ends? As accuracy of position was of the very first necessity, the knocking-over bar had to be supported at intervals, and so the connectors—which were thin pieces of steel passing between the threads of the warp—became necessary, for stretching these connectors was a very different matter to what simply bending the bar would be. A very small force would cause deflection of the latter, while a tensile tress on the former would give no visible result. He could not claim credit for the invention of the hooked needles, as they had been brought before the world some 130 years ago by William Lee, and were now a part of every hosiery machine. They were made entirely by machinery, except the bending over, and the depression to take the point was punched. Up to about twenty-five years ago, this punching had been done by hand, but it was now done by a machine. As to wear and tear or durability, the new machine had only been running for such a short time that it would be obvious he could not speak from actual experience on this point. Nevertheless, he could form a strong opinion inferentially. The first knitting machine he had made in 1863 was still running and doing excellent work. The parts that would be liable to wear in the new machine were similar to those used in the knitting machine, and, therefore, he concluded that one would have as long a life as the other.

The president in moving a vote of thanks to the author—a vote which was heartily accorded—spoke of the advantages of substituting the chains described for the old Jacquard cards.

THE CORROSION AND FOULING OF STEEL AND IRON SHIPS.*

By Prof. V. B. LEWES.

THE difficulty of obtaining adequate experimental data, and the fact that nearly every one who has worked at the subject has had a composition of his own to bring before the public, has so hampered and restrained the free discussion and interchange of ideas on this most important question, that at the present time we have made but scant progress beyond the point reached twenty years ago, and my object in bringing this paper before you is more to excite you to discussion, and to show you the known facts of the case, than to tell you of any very new or startling discoveries.

Corrosion generally precedes fouling on exposed metal surfaces, and it is therefore this portion of the subject that will be considered first, together with the means which have been taken to prevent it and to protect the plates of our vessels from decay.

In a paper which I had the honor to bring before you two years ago, I pointed out that in all processes of rusting, carbonic acid gas and moisture played an important part, the iron uniting with the carbonic acid and oxygen of the water to form ferrous carbonate while the hydrogen was set free, and that the ferrous carbonate then took up oxygen dissolved in the water or present in the atmosphere as the case may be, and was decomposed into ferric oxide (rust) and carbonic acid, which being liberated in actual contact with the moist surface of the iron, carried on the process of "rusting."

This view of the case was confirmed by a paper read by Prof. Crum Brown before the Iron and Steel Institute, at Edinburgh, last autumn, and is generally accepted as the true explanation of the corrosion taking place on iron or steel surfaces exposed to moist air or fresh water; but the rusting of the metal in sea water has by many chemists been ascribed to a more complex action, in which the salt present plays an important part by first forming oxychloride of iron.

This preliminary stage of corrosion in sea water is, I am inclined to think, a myth. When iron filings or turnings are exposed to the action of sea water, hydrogen gas is evolved, and ferrous oxide and carbonate are formed, and this changes, as in air or fresh water, into ferric oxide, by taking up dissolved oxygen present in the water. At no time have I been able to detect the presence of oxychloride, and from the fact that a few drops of alkali added to the sea water stop the corrosion, I am of opinion that the simple rusting of iron in sea water is due to the same cause as in fresh—*i. e.*, the decomposition of the water by the iron in presence of carbonic acid.

The saline constituents of sea water, however, do undoubtedly play an important part in a more active form of corrosion, by helping to excite galvanic action between the iron in the plates and any foreign metal or impurities present, an action which is also materially aided by want of homogeneity in the metal, by particles of rust, by mill scale, by wrought and cast iron or steel in contact with each other; or even by the different amount of work, such as hammering or bending, undergone by different parts of the same plate; and in all of these cases the galvanic action set up causes rapid oxidation of the iron at the expense of the oxygen of the water, hydrogen being evolved.

We may therefore consider that on the skin of a ship two processes of rusting are going on, the simple corrosion on exposed surfaces of the metal, due to the presence of moisture, carbonic acid, and free oxygen, which forms a fairly uniform coating of rust on the metal, and the more local corrosion due to galvanic action, which results in pitting and uneven eating away of the plates.

As I pointed out in a previous paper, rust cones are due to the most local form of galvanic action, caused by the presence of a speck of deposited copper, lead, or other foreign metal, or even a small particle of rust or mill scale left on the surface of the iron, and covered by the compositions used as protectives and anti-foulers; as soon as the sea water penetrates to these, galvanic action is set up, water is decomposed, rust formed, and the escaping hydrogen pushes up the composition, forming a blister, the hydrogen leaks out, the water leaks in, the action becoming more and more rapid, and the blister gradually filling with the result of the action—rust. The blister bursts, but the cone of rust has by this time set fairly hard, and continues to grow from the base, the layers of rust being perfectly visible in a well-formed cone, and when the rust cone is detached, the pitting of the metal at the base of the cone is, as a rule, found to be of considerable depth.

The speck of foreign matter which has caused this destructive action generally clings to the surface of the iron, and, being at the bottom of the pitting, escapes detection and removal, and when the vessel, newly coated with fresh compositions, again goes to sea, the corrosion will again probably be set up in the same spot.

* A paper read at the thirtieth session of the Institution of Naval Architects, by Prof. V. B. Lewes, F.C.S., F.I.C., Royal Naval College Associate, on April 12, 1889.

The corrosion of the plates in the interior of a vessel is a subject quite equal in importance to the external action of sea water and dissolved gases on the metal; and from the fact that certain portions of the interior plates, from their position, escape the frequent examination and attention bestowed upon the exterior, it becomes a still greater source of danger.

Corrosion, like all other forms of chemical action, is much accelerated by increase of temperature; and in the bottom of a ship, near the furnace room and boilers, this has a considerable effect in increasing rapidity of rusting. Also in the coal bunkers, the mere contact of moist coal with iron plates sets up galvanic action, carbon being electro-negative to iron, and the coal dust which sifts down into the double bottom lends its aid to the destruction of the plates; while if the coal contains any "pyrites," which is nearly always the case, these double sulphides of iron and copper are gradually oxidized into soluble sulphates of the metals, and these, washing down into the bilge water, would at once cause most serious corrosion, should they come in contact with any bare portion of the plates. Repairs to any portion of the inside plates will loosen rust and mill scale, which, finding its way into the bottom, tends to set up galvanic action; while the scale of oxide of copper from copper and brass fittings and pipes is another great cause of danger, as the bilge water would gradually convert it into soluble salts, which will deposit their copper upon the iron wherever a crack or abrasion enables them to come into contact with it; and finally, leakages from stores and cargo are in many cases of a character highly injurious to iron.

In addition to all these sources of danger, we must remember that the interior of the vessel is the part most liable to abrasion from shifting and moving of cargo, coals, etc.

The protection of the outsides of the bottoms of our ships from the destructive agencies of sea water and dissolved gases may be said to have been attempted in two ways—by metallic and by non-metallic coatings.

So far, all attempts at metallic coatings have proved failures, and, as far as it is possible to judge, there is but small likelihood of their ever being made to succeed, because if zinc is used in order to protect the iron of the ship there must be galvanic action, and this action must take place evenly all over the surface of the iron plates, which means that the sheathing must be in uniform metallic contact with the iron, in which case the wasting of the sheathing would be so rapid that it would have to be renewed frequently, which, even leaving out the question of cost, is in many cases impossible.

Zinc is practically the only metal which could be used for this purpose, in order to place the plates of the ship in an electro-negative condition, and it is therefore to zinc that inventors have turned from time to time, the chief novelties introduced being the method of attachment. As far back as the year 1835, I believe Mr. Peacock tried zinc plates on the bottom of H. M. S. Medea, and in 1867 Mr. T. B. Daft again brought the subject forward; Sir Nathaniel Barnaby, Mr. McIntyre, and others also suggesting various plans of attachment, while as late as last year Mr. C. F. Henwood read a paper at the United Service Institute strongly advocating zinc sheathing as attached by his system. Where the galvanic contact has been but small, there the sheathing has had a certain life, but has afforded but little protection to the iron, and has gradually decayed away in a very uneven fashion; while in those cases where galvanic contact has been successfully made, the ship has on several occasions returned from her voyage minus a considerable portion of the sheathing.

Another drawback to the use of zinc sheathing is one which was found when it was used to coat wooden ships, and that is that zinc when in sheets, like every other metal, is by no means homogeneous, and that for this reason the action of sea water upon it, leaving out of consideration galvanic action, is very unevenly carried on, the sheathing showing a strong tendency to be eaten away in patches, while the metal itself undergoes some physical change, and rapidly becomes brittle.

Attempts have been made to galvanize the iron before the building of a ship; but Mr. Mallet showed as early as 1843 that this coating was useless when exposed to sea water, as in from two to three months the whole of the zinc was converted into chloride and oxide, and that when, therefore, galvanizing is used, care must be taken to protect the thin coating of zinc. This does not, of course, apply to fresh water, in which galvanized iron would answer very well, the rapid action being due to the salts in the sea water; but even in this case the galvanizing would have to be done after the plates had been riveted together, as any breaking of the surface would set up rapid wasting of the zinc, and it could, therefore, only be used on small craft.

Copper, tin, and lead have been proposed for coating ships, but these metals are electro-negative to iron, and would rapidly destroy the hull, should any abrasion of the coating or damage to the insulating material take place.

The non-metallic coatings which are intended to do away with corrosion have been almost endless. At the present moment there are upward of thirty in the market; while the patent list of the last fifty years contains an enormous number which were practically stillborn.

They may be divided for convenience into—

(*a*) Oil paints.

(*b*) Pitch, asphalt, tar, or waxes.

(*c*) Varnishes consisting of resins and gums dissolved in volatile solvents.

(*d*) Varnishes containing substances to give them body.

(*e*) Coatings of cement.

And, before going into these in detail, it is necessary to consider the condition of the surfaces to which they will have to be applied and the effect this will have upon them.

Air has the power of holding water vapor in suspension, the amount so held being regulated by the temperature; the higher the temperature, the more can the air hold as vapor, while any cooling of the air saturated at the particular temperature causes a deposition of the surplus moisture. When a ship is scraped down to the bare iron in the dry dock, we have a huge surface of metal which varies in temperature much more rapidly than the surrounding air, and cools much more rapidly than the stone walls of the dock; as it cools, so it chills the layer of air in immediate contact with it, and causes a deposition of the surplus moisture on its surface—a phenomenon known as the "sweating of iron"—and on to this moist surface the protective composition has to be painted. If now a rapidly drying varnish is put on, the rapid evaporation of the volatile solvent causes again another sudden fall of temperature—evaporation being always accompanied by loss of heat—and this fall of temperature again causes a deposition of moisture, this time on the surface of the protective, so that the coating is sandwiched between two layers of moisture, both of them probably acting deleteriously upon the resin or gum in the varnish, while the moisture on the iron also prevents adherence of the varnish to the metal. If, instead of a quick-drying varnish, the old fashioned red lead and linseed oil protector had been used, the second deposition would not have taken place, but the sweating of the iron would have prevented cohesion, and, when dry, any rubbing of the coating would bring it off in strips.

The condition of the outer skin of a ship, when she is being coated with her protective composition, is one of the prime factors in the discrepancies found in the way in which compositions act. It being a very usual thing for a composition to give most satisfactory results on several occasions, and then, apparently under exactly similar circumstances, to utterly break down, and to refuse even to keep on. Too much stress cannot be laid upon the condition of the plates at the time of coating, and it is absolutely essential either to have a perfectly dry ship or else a composition which is not affected by water.

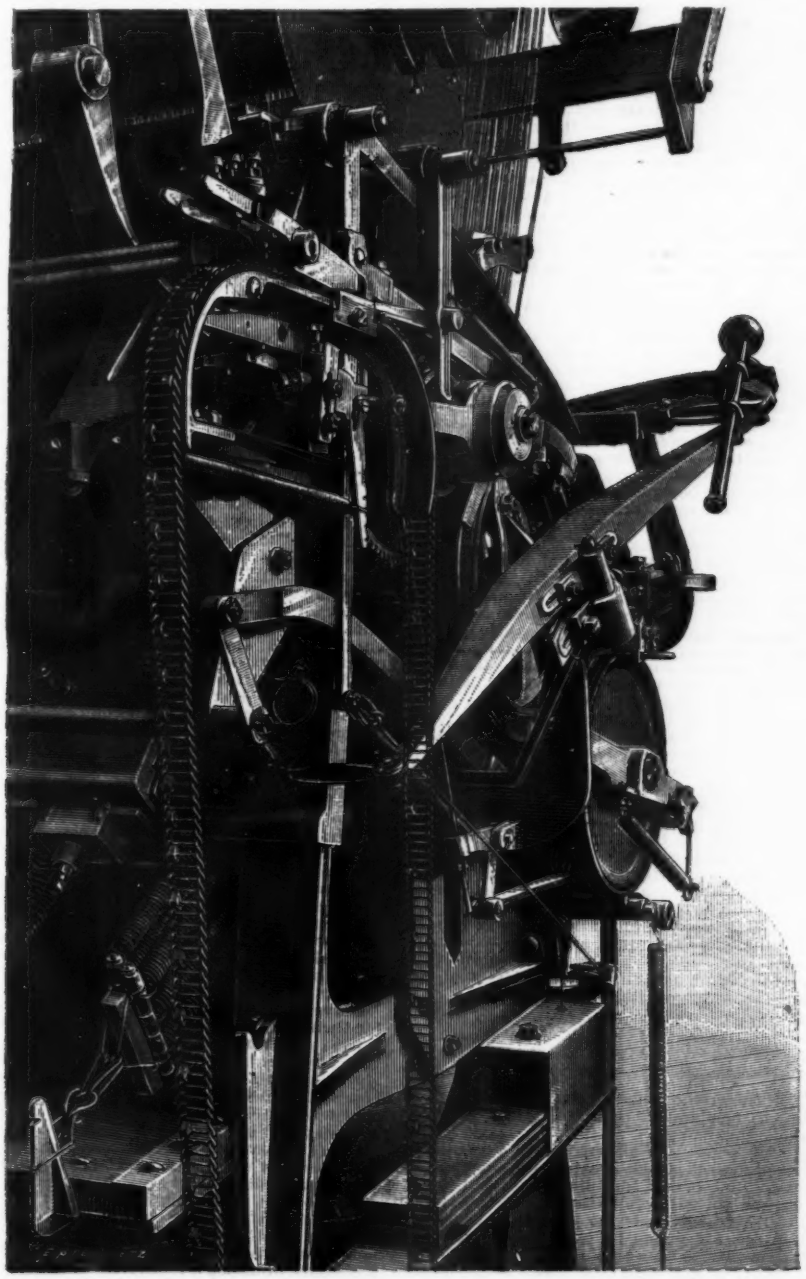
When an old ship is broken up, you will often see on the backs of the plates the numbers which have been painted on them with white lead and linseed oil before the ship was built, and under the paint, the iron in a perfect state of preservation, the secret being that the paint was put on while the plates were hot and dry.

Boiled linseed oil, mixed with red or white lead, is among the oldest of the protective compositions in use, but of late years has been but little employed, since it was proved by M. Jouvin, of the French navy, and also in this country, that compounds of lead, when exposed by the wasting of the vehicle to the action of sea water, are converted into chloride of lead, and this is rapidly acted on by the iron, depositing metallic lead and forming chloride of iron, the deposited lead carrying on the corrosion of the iron by rapid galvanic action. The drying of boiled linseed oil is due to the fact that it has in it a certain quantity of an organic compound of lead, and the drying properties are given to it by boiling it with litharge (oxide of lead), so that even when red or white lead is not mixed with it, still lead compounds are present, and this action will go on to a lesser extent. When the boiled oil dries, it does so by absorbing oxygen from the air, and becomes converted into a sort of resin, the acid properties of which also have a bad effect upon iron, so that protectives containing boiled oil are open to objection. Within the last two months a good example of the action of sea water on the bottom of an iron ship, coated with red lead, has been afforded by H. M. S. Nile, which, after being painted over with coats of red lead, was allowed to remain for some months in Milford Haven, with the result that her bottom is very seriously corroded, and, on examination of specimens of rust taken from her, the crystals of metallic lead are in many cases easily identified.

If red lead is used, it can only form a groundwork for an anti-fouling composition which has to protect the red lead as well as the iron of the ship from the action of sea water, and when the anti-fouling composition and the vehicle perish, then serious corrosion must ensue.

The second class of protectives, consisting of tar and tar products, such as pitch, black varnish, and also asphalt and mineral waxes, are among the best protectives, the waxes especially not being affected by the sweating of the plates, and forming admirable coatings for the plates. Certain precautions, however, must be taken in the case of tar and tar products, both of which are liable to contain small quantities of acid and of ammonia salts; but if care be taken to eliminate these, and if it could be managed to apply this class of protectives hot to warm plates, the question of protection would be practically solved, bituminous and asphaltic substances forming an enamel on the surface of the iron which is free from the objections to be raised against all other protectives, that is that being microscopically porous they are pervious to sea water.

The third class of protectives consists of varnishes formed by dissolving gums or resins in volatile solvents, such as spirit, turpentine, naphtha, fusel oil, etc., and such varnishes are open to several objections; in the first place, they are acted upon by moisture, which causes a deposition of the resins or gums as a non-coherent powder and destroys tenacity of the varnish. The amount of action which moisture has on such a spirit varnish depends to a considerable extent upon



THE PAGET WARP WEAVER AND KNITTER.

the proportion of resin or gum to spirit, when the solvent is present in large quantities, and the resin in comparatively small; then the moisture has apparently little action; but it must be remembered that the drying of such protectives means the rapid evaporation of the solvent and concentration of the resin or gum, while the rapid volatilization which is going on cools the hull of the ship, and causes deposition of moisture on the drying varnish, with most disastrous results.

Another point which must be borne in mind is that no such varnish is impervious to gases and liquids. We are apt to think of a coating of varnish as being perfectly homogeneous; but, on examining it through a microscope, it is seen to be full of minute capillary tubes, which become gradually enlarged by the action of water, and finally result in the destruction of the varnish, while moisture and dissolved gases find their way to the metal, and carry on corrosion. The application of several coats of varnish tends to diminish this evil, as in many cases the holes in the first coat will not correspond with the holes in the second, and so each succeeding coat will tend to make the protective more and more impervious. In using such varnishes, they must only be applied in favorable weather, and must be allowed to thoroughly harden before being brought in contact with the water.

In the fourth class we have varnishes of this kind to which body has been given by the addition of foreign constituents, generally mineral oxides; and this class is far preferable to the last, if the solvent used is not too rapid in its evaporation, and if care has been taken to select substances which do not themselves act injuriously upon iron or upon the gums or resins which are to bind them together, and are also free from any impurities which could do so.

At present the favorite substance used to give color and body to such varnishes is the red oxide of iron, the color of which effectually cloaks any rusting which may be going on under it. In using the red oxide for this purpose, care should be taken that it contains no free sulphuric acid or soluble sulphates, as these are common impurities, and are extremely injurious, tending to greatly increase the rate of corrosion. The finest colored oxides are, as a rule, the worst offenders in this respect, as they are made by heating green vitriol (sulphate of iron), and in most cases the whole of the sulphuric acid is not driven off, as the heat necessary impairs the color. This acid is often neutralized by washing the oxide with dilute soda solution, but very little trouble, as a rule, is taken to wash it free from the resulting sulphate of soda, which is left in the oxide.

A sample of exceptionally good color intended for using in protective compositions was sent me a few weeks ago for analysis, and proved to contain no less than 15·3 per cent. of sulphate of soda.

The best form of oxide of iron to use for this purpose is obtained by calcining a good specimen of hematite iron ore at a high temperature. When prepared in this way, it contains no sulphates, but from 8 to 40 per cent. of clay; if the percentage does not, however, exceed 12 to 18 per cent., it is perfectly harmless.

Composition manufacturers can easily test their red oxide for themselves, to see if it contains soluble sulphates, by warming a little of it with pure water, filtering through blotting paper, and adding to the clear solution a few drops of hydrochloric acid and a little solution of chloride of barium (easily obtained at any druggist's). If a white sediment forms in the solution, the sample should be rejected.

In a previous paper* on the corrosion and protection of iron and steel ships, I pointed out that when such a varnish perished, the oxide of iron being left in contact with the iron plates, increased the corrosion going on at the surface of the metal, all oxides being electro-negative to the metals from which they are produced, and on that occasion I advocated the use of finely divided metallic zinc, which can be obtained as an impalpable powder, in place of the oxide of iron, pointing out that such a composition would last as long as any varnish of this class, and that, when the varnish perished, as it must do after long exposure to sea water, then the metallic zinc would, on coming in contact with the iron, set up galvanic action; but that, instead of being electro-negative, as in the case of oxide of iron, and causing corrosion of the plates, it would be electro-positive, and in consequence would protect them, being itself slowly oxidized, and so would give a fresh period of protection.

I hoped at the time that I had made it perfectly clear that the zinc would in no way act until both the anti-fouling and protective varnish had perished, and had become spongy and porous, and that the idea was a prolongation of the period of protection, the great point which has now to be aimed at; but the remarks made afterward in several journals which were kind enough to notice my paper showed me that they had mistaken my intention, and supposed that the zinc was put in to at once create galvanic action, and predicted that if by any chance it did act, the hydrogen generated would blow the composition into blisters, and defeat its own purpose. I need hardly point out that nothing was farther from my intention, as zinc in fine powder will be acted on more rapidly than the dense metal in plates, and I have already pointed out that this is destroyed too rapidly by galvanic action to render it of practical use as a protective *per se*.

As to the hydrogen blowing off the composition, no gas could be generated until both the anti-fouling and the protective coatings had perished and were rendered perfectly porous by the action of the sea water, a condition which would have permitted the free escape of the generated hydrogen, which, it must be remembered, will permeate through openings which other gases cannot pass through.

One of the largest firms of composition manufacturers had enough curiosity to try the effect of zinc *versus* oxide of iron, and painted a patch of it upon a ship coated with their compositions, and after a long voyage she returned with her protectives in perfectly good order, and had it not been for the patch containing zinc having had its position fixed by careful measurements, its whereabouts could not have been discovered. This is exactly what one would have expected; as long as the varnish remains intact, oxide of iron, zinc, or, indeed, any substance which will not damage the varnish, does perfectly well; but had the vessel been allowed to continue until the varnishes had perished, then I venture to say that the patch containing the zinc would have shown better protection than those parts containing the oxide of iron. My ideas have undergone considerable modification during the past two years, but I still consider the views I put forward in my last paper were perfectly sound, and I am every day more and more convinced that the great object the composition maker has to aim at is the prolongation of the life and effectiveness of compositions, and not the multiplication of short-lived devices, however admirable in their action.

In the fifth class of protectives we have cement coatings; but these, together with such schemes as the covering the hull of the vessels with vitreous glazes, glass, etc., have of late years, as far as I know, entirely been abandoned. The action of cement on iron, however, must later on be discussed in its important bearing on the protection of the interior portions of the hull, for which it is largely employed, its weight and the difficulty of attachment rendering it unfitted for outside work.

In selecting a protective composition for the bottom of a vessel, one of the second or fourth class should be chosen, attention being given to the points I have indicated, which are that in the bituminous and asphaltic compositions all the original acids must be eliminated, and that in the varnishes of the fourth group quickly evaporating solvents should be avoided, and, if possible, zinc substituted for oxide of iron.

The vessel should have her plates as dry as possible during the application of the protective, and, if feasible, days on which the air is fairly dry should be chosen. The protective should not be too thick, as, if it is, it does not readily fill into inequalities in the plates; and, if in this way any air is inclosed, change of temperature will cause it to expand or contract, thus causing a blister to form, which will fill with sea water and set up rapid corrosion. The composition must either be elastic or else have the same rate of expansion and contraction as the iron; for, if not, the change of temperature will cause cracking and tearing of the composition with disastrous results. The vessel, if she has to be scraped down to the bare metal, must be scrubbed free from all traces of rust, and where a well-adhering coating of composition exists, it should be painted over and not disturbed. In the case of a new ship, she must be pickled with dilute acid, to get rid of every trace of mill scale, and then washed down with some slightly alkaline liquid to neutralize every trace of acidity, the alkali in turn being removed by clean water. Under these conditions, and given a composition with good adhering properties, but little apprehension need be felt as to the ravages of corrosion on the metal of a ship's bottom, the chief risk being from abrasion and other mechanical injury to the composition, coupled with improper constituents in the anti-fouling compositions. The protection of the interior portion of the vessels, where the plates are exposed to the corroding action of bilge water, rendered more active by a high temperature, leakage from cargo, acids and sulphates from wet coals, and the presence of such electro-negative factors as coal dust, scale, and rust, is a matter of quite as great importance as the exterior protection; while the great chance of mechanical abrasion during coaling and shifting of cargo, as well as the difficulty of getting at the lower portions of the hold to examine the condition of the plates, renders it a question of the gravest consideration. The corrosion found in the portions underneath the engine seats, the bunkers, and the water-ballast chambers, especially near the engine room, is often very serious, and needs most careful watching, which, from the position of these parts of the vessel, it is very hard to bestow upon it.

It must also be remembered that the bilge water in a vessel is in constant motion, and that the air in these parts of the vessel may be expected to be exceptionally rich in carbonic acid gas, which, as I have before shown, is the most important factor in corrosion. Under these conditions any abraded portion would probably be continually washed over, and then exposed to the foul air, a condition of things most conducive to rapid rusting. There are three main classes of protectives for the interior of a ship:

1. Cements.
2. Bituminous coatings.
3. Paints.

The first of these, the cement coatings, have many good points to recommend them, but they also have many serious drawbacks.

The rigidity, firmness of adherence, and endurance are all of them points of the greatest importance, and there is no doubt but that the silicates present in the cement in time not only bind the cement into a mass of wonderful hardness, but also bind that cement to the iron. A point to which I should like to draw your attention, however, is that a thin coating of Portland cement is highly porous, and that it can be permeated by liquids and gases. Suppose, now, that some copper scale from the interior fittings had fallen into the bottom of the vessel, and had been converted into soluble salts of copper by the saline bilge water, this solution would soak through the capillary orifices in the cement until it came in contact with the iron below, when the copper would be deposited on the iron, and rapid galvanic action set up, the cement being loosened, and to a certain extent lifted, by the formation of rust, while corrosion would gradually extend under the cement, giving on the outside of the coating but little sign of damage taking place below it.

Also the hardness and rigidity of the cement gives it a tendency to crack away from the metal when any strain is thrown upon the plates, or during any expansion or contraction of the metal; while any repairs on the outside of the ship, such as making a boring to test the thickness of plate, replacement of rivets, etc., would undoubtedly cause a loosening of the cement coating within, and wherever a loosening takes place, the space between the cement and the plate will quickly be found to become a starting point for corrosion, which quickly spreads and loosens the cement, and will only be discovered by chance.

It is for this reason that I consider bituminous or asphaltic varnishes, freed from any trace of acid, and applied hot, or sound tough paint, preferable to cement; as, although they are not so hard, yet if serious corrosion should be set up, it is easily discovered and stopped before much damage results, while, being impervious to moisture, deleterious solutions, either from the coal bunkers or cargo, would be prevented from acting upon the skin of the ship.

In approaching the subject of fouling, one is impressed with the apparent hopelessness of obtaining any reliable information from the successes or failures registered by the bottoms of the vessels in the service or in the mercantile marine. Hundreds of ships may be examined, and their condition and the nature of the compositions used upon them registered, and just as one begins to feel that the key to the mystery is within one's grasp, a whole series of results so abnormal suddenly comes to light that it seems impossible to reconcile them with one's previous experience. A ship may sail half a dozen times to the same waters, coated with the same composition—on four occasions she will come home clean and in good condition, while on the other two voyages she may accumulate an amount of weed and animal life sufficient to knock down her speed from nine knots to five.

Moreover, if the compositions with which she was coated be examined, and scrapings taken from her on her return, no cause will present itself that can in any way explain the great difference in her condition. After several years of close observation, however, certain factors begin to make themselves apparent. Ships at sea from March to August show a worse average than those afloat from August to March; one also begins to realize that the amount of fouling increases enormously if the ship has been long at anchor—ships which have been lying at the mouths of rivers, although quite clean in the brackish water, foul much more rapidly on going to sea than the vessels which have been cruising, or even at anchor for the same time in salt water; and finally, certain ports and certain seas seem to exercise a deleterious effect, both as regards corrosion and fouling, which is not to be found elsewhere.

Turning back to the naval history of the past, we find that fouling is no new trouble born with the advent of our present iron monsters; but that it has been the one trouble that the combined engineering and scientific skill of many centuries has been unable to overcome.

With our wooden ships, metallic copper sheathing, if it were of the best kind, answered the purpose fairly well; but then the copper wasted so fast that inferior kinds and alloys were substituted to prevent the rapid loss, and, with the slowing down of the destruction of the copper, at once the trouble of fouling returned.

When iron ships began to replace the wooden ones, as was only natural, attempts were made to utilize the metal which had before given relief; but it was quickly found that the effect of the galvanic action set up by the copper was fatal to the iron plates of the ship, and attempts were then made to sheathe the ship with copper plates in such a way that they should be insulated from the iron of the vessel, a condition almost impossible to attain and attended with great risk should any accidental injury to the insulation take place.* Early in the history of iron shipbuilding the idea was started of using coatings of paint, so prepared as to fulfill the same functions as the copper plates had done; but from 1840, when the first paint of this kind was patented, down to the present day, when there are upward of thirty-two different compositions in the market, very little progress has been made in their manufacture, and the best of their compounds cannot be relied upon for keeping a ship's bottom even fairly free from fouling for periods extending beyond nine months, and I am personally convinced that the reason of this is to be found in the fact that a start was originally made in the wrong direction.

The idea which originally led to the present class of anti-fouling compositions was that the copper salts formed by the action of the sea water on the metallic sheathing owed a considerable portion of their value as anti-foulers to the poisonous action they exerted upon marine animal and vegetable growths; but, when an observer comes to study the natural history of these lower forms of animal life and vegetation, it is gradually forced upon one that it is only in the early stages of their growth—the germ period—that metallic poisons can affect them.

Seaweeds do not take in the constituents they require for their growth by means of their roots, as is, to a certain extent, the case with ordinary plants, but absorb them by means of their pores from the water itself, the root only serving to attach them to the solid they choose for their resting place; it is also well known that when once a marine plant which has passed the first stages of existence is dislodged or torn from its support, it cannot reattach itself to anything else, while most of the mineral poisons have little or no effect upon their life and growth.

In the same way we find that, with the animal life found on a ship's bottom, the under side is used to cling on with only, and not as an extractor of nourishment, and that, therefore, after the seeds and germs have once obtained a foothold on the side of the vessel, no amount of poison which can be put into a composition will have any effect upon them. Metallic poisons undoubtedly do exert an influence upon the germs in their earliest stages; but after that they are perfectly useless as anti-foulers, and only imperil the plates of the vessel.

The germs of both kinds of growth are of necessity more abundant in the surface water near shore than in deep water, and therefore the period when the ship is in port is the time when the germs are most likely to make good their attachment, after which their further development is, unless other methods of getting rid of them are employed, merely a matter of time.

On examining the conditions under which a vessel is placed when coated with a composition which relies for its anti-fouling powers on metallic poisons only, we at once see the reasons which must make such a coating of little or no avail. In the composition we have drastic mineral poisons, probably salts of copper, mercury, or arsenic, which have been worked into a paint by admixture with varnishes of varying composition, and each particle of poison is protected from the action of the sea water by being entirely coated by this vehicle; that this must be so is evident, or the composition would not have sufficient cohesive power to stick on the ship. As a rule, care is taken to select fairly good varnishes, which will resist the action

* Transactions of the Institution of Naval Architects, vol. xxviii.

* Some copper-sheathed vessels still exist, and its revival has been lately warmly advocated in America.

of sea water for, perhaps, two or three months, before they get sufficiently disintegrated to allow the sea water to dissolve any of the poison; while even with the accidental or intentional use of inferior varnishes, three or four weeks will pass before any solution can take place, and any poison be liberated to attack the germs. A ship is dry-docked, cleaned, and, her anti-fouling composition having been put on, she goes probably into the basin to take in cargo. Here she is at rest, and, with no skin friction or other disturbing causes to prevent it, a slimy deposit of dirt from the water takes place, and this, as a rule, is rich in the ova and germs of all kinds of growth, while the poisons in her coating are locked up in their restraining varnish, and are rendered inactive at the only period during which they could be of any use. After a more or less protracted period, the ship puts to sea, and, the perishing of the varnish being aided by the friction of the water, the poisonous salts begin to dissolve or wash out of the composition; but the germs have already got a foothold, and with a vessel sweeping at a rate of, say, 10 to 12 knots through the water, the amount of poison which can come in contact with their breathing and absorbing organs is evidently so infinitesimally minute that it would be impossible to imagine it having any effect whatever upon their growth. If the poison is soluble, it is at once washed away as it dissolves; if it is insoluble, then it is also washed away, but there is just a chance that a grain or two may become entangled in the organs of some of the forms of life, and cause them discomfort. As the surface varnish perishes, the impact of the water during the rapid passage of the vessel through the water quickly dissolves out or washes out the poisonous salts, and leaves a perished and porous but still cohesive coating of resinous matter, which forms an admirable lodgment for anything which can cling to it; and by the time the vessel lays to in foreign waters, teeming with every kind of life, the poison which would now again have been of some use is probably all washed away, and a fresh crop of germs are acquired, to be developed on the homeward voyage, and a "bad ship" is reported by the person who looks after her docking. It is evident that a poison, even if it had the power of killing animal and vegetable life in all stages, could only act with the vessel at rest, unless it were of so actively corrosive a nature as to burn off the roots and attachments of the life rooted to it, and if it did this, what, may I ask, would become of the protective composition and the plates of the vessel? And I think it is also evident that any poison so used must be under conditions in which it is very unlikely to be in a position to act when it might do good.

The lamentable failure of composition after composition of this kind has gradually reduced them in number to some ten or twelve at the present time, and in most cases it is low price alone which keeps them in the market.

The practical proof, given by experience, that poisons alone are unable to secure a clean bottom, soon led many inquirers to the conviction that it was the exfoliation in the case of copper which had acted in giving fairly good results, and in many compositions the attempt has been made to provide a coating which shall slowly wash off, and, by losing its original surface, shall at the same time clear away germs and partly developed growths, and so expose a continually renewed surface, in this way keeping the bottom of the vessel free from life. There is no doubt that, when this is successfully done, a most valuable composition will result, but the practical difficulties which beset this class of anti-foulers must not be overlooked. In order to secure success, the composition must waste at a fairly uniform rate, when the ship is at rest, and also when she is rushing through the water; and this is the more important in the case of service vessels, as in many cases they spend a large percentage of their existence at anchor or in the basins of our big dockyards. If a composition is made to waste so rapidly that it will keep a vessel clean for months in a basin, then you have a good composition *for that purpose;* but send the vessel to sea, and under conditions where you have a higher temperature, and the enormous friction caused by her passage through the water exerting its influence upon the composition, and you will find that the coating, which did its work well for six months at rest in the basin, will, in the course of one month under these altered conditions, be all washed away, and fouling will be set up. Noting this result, the manufacturer renders his composition more insoluble—less wasting—and so obtains a coating which, when the vessel is in motion, scales just fast enough to prevent fouling, and good results at once follow; the composition is then put on the same or other vessels, and they take a spell of rest in the basin, and, bereft of the aid of the higher temperatures and the friction of the water, the composition ceases to waste fast enough, and bad results at once have to be recorded.

There is no doubt that this is the true explanation of the wide discrepancies which are found between the compositions in the navy and in the mercantile marine; take any of the big lines, their steamers are running at a fairly uniform rate of speed, and the periods of inaction are as short as the desire not to waste the charge on the capital they represent can make them, and under these conditions, by varying the constituents in the varnishes used for anti-fouling purposes, it is fairly easy, giving the necessary data, to so constitute a composition as to secure admirable results; but when you come to apply this same coating to an ironclad running at various speeds, and as often at rest as in motion, then you at once find that the composition you before imagined to be all that could be desired fails just as lamentably as the tribe of anti-foulers which preceded it. It is not so very long ago that I had the honor to serve on an Admiralty committee under the able guidance of Admiral Colomb, and, after inspecting many vessels in the mercantile marine, and watching all the dockings of service vessels over a considerable space of time, we were forced to the conviction that it was only in very rare cases that the condition of the bottoms of her Majesty's ships at all approached the freedom from fouling to be found in the ships belonging to the big companies, with the result that some of the most successful of the compositions in the mercantile marine were brought into use in the navy, and I believe the reports of the dockings since they have been adopted will amply prove the existence of the difficulties I have mentioned.

Another factor which is often overlooked, and which tends to give misleading results, is the action of brackish water, which in many cases seems to exert a special action in keeping the bottom of a vessel clean, the fresh water having a tendency to disagree with certain forms of marine growth, while the salt water is apparently equally unpalatable to the fresh water forms of fouling.

In most of the compositions now in use, attempts are made to combine strongly poisonous substances with exfoliating and wasting coatings, and this is done by either using metallic soaps, the basis of which is, as a rule, copper, or else by charging a perishable and easily washed-off varnish with poisonous salts, consisting, as usual, of compounds of either copper, mercury, or arsenic, and in some cases all three.

As I have before pointed out, I do not think the presence of these substances exerts any deterrent action upon the fouling, save perhaps when the vessel is at rest; but they exert undoubtedly an important influence upon the rate of exfoliation, as when the perishing of the varnish exposes them they dissolve, or are washed out, and in this way tend to disintegrate and clear away the surface more rapidly—an important and decidedly useful function, but one which might be more cheaply performed by substances other than high-priced metallic poisons.

The use of metallic poisons of the character indicated throws an increased burden upon the protective composition, as, should the latter become abraded by friction of chain cables, barges alongside, or any other cause, the iron of the vessel will be attacked by the metallic salts, either present in the soluble form in the anti-fouling composition, or rendered so by the solvent action of the saline constituents of the sea water, the action of the metallic salts being to rapidly dissolve portions of the iron, and to deposit the metal which they contain upon the surface of the plates, and these deposits, exciting energetic galvanic action, cause corrosion and pitting to go on with alarming rapidity.

Both mercury and copper salts are offenders in this way, but copper is by far the most objectionable, from the fact that the salts formed by the action of the sea water upon the compounds used in the compositions are far more soluble than the corresponding salts of mercury, and are therefore liable to be present in much larger quantity, and so exert comparatively a much more injurious action on the plates.

As an illustration of this, two equal portions of sea water were saturated, the one with copper chloride, the other with mercuric chloride, and into each a piece of steel, planed upon one side, and of about equal weight and size, was placed and left for four days. At the end of this period the two plates were removed, and, after being cleaned and dried, were again weighed, when it was found that the one exposed to the copper-saturated sea water had lost 22·2 per cent. in weight, while the plate exposed to the mercurial solution had only lost 3·6 per cent., this being due to the much larger amount of the copper salt soluble in the sea water.

On now placing these plates in clean sea water, corrosion went on in each case with extreme rapidity, and after being exposed for a month, they had both wasted to about the same extent—that is to say, when once deposited on the iron, mercury is practically as injurious as copper.

I am quite aware that this experiment is not at all likely to be carried out in practice, and none can have a greater conviction of the inutility of small laboratory experiments than I have, as they lack all the factors of mass of material and atmospheric influence which play so important a part in a question like the present; but such an experiment gives one a definite and fairly correct idea of the relative rate of action of the two poisons upon the plates.

All the time the ship is in motion, the wash of the sea water will prevent the metallic poisons doing the plates or the marine growths much harm, but there is one phase of this question which I think has been overlooked. I need not point out that in certain ports there is a fashion in compositions, and that most of the homes of the mercantile marine have some pet local composition which is largely used at that particular port. If, now, many ships are lying in a basin, taking in and discharging cargo, and if the prevalent compositions contain copper, it is evident that a certain quantity will go into solution in the water, which often does not undergo frequent or rapid change, and under these conditions every ship in the basin will be exposed to the same danger, and wherever an abrasion has taken place in the protectives, there copper will be deposited on the iron, causing corrosion and destruction of the plates; and it must be remembered that when the vessel is next docked and coated, no amount of scraping will remove the fine particles of copper deposited in the pitted and corroded portions of the plate, and so finely divided as to be invisible to the eye, but that they will remain and carry on the destructive work under the new coatings of the protective.

It is, I think, a well recognized fact that, when a vessel coated with a copper compound has become corroded from failure of her protective, or from abrasion, even an entire change of composition does little or no good in stemming the tide of corrosion until after some considerable period has elapsed, a result which is due to the same cause; and inasmuch as copper compositions are a source of danger, not only to the ships coated with them, but to any others which may be at rest in the same basin, I do strongly urge upon the manufacturers to abandon the use of these deleterious compounds, and to use others equally efficacious and free from the grave objections I have enumerated.

At the present time, fifteen out of thirty-two principal compositions rely upon copper in some form or other as the basis of their anti-fouling composition, and in one which has enjoyed considerable favor finely divided metallic copper itself is used; and should a vessel coated with it, after the varnishes had commenced to disintegrate, be moored alongside an iron ship by a chain cable, or even by a wet hawser, a big galvanic couple would be formed at the expense of serious damage to any exposed iron.

In the history of anti-fouling many attempts have been made to obtain highly glazed and glass-like surfaces which it was hoped would withstand the action of sea water, and afford no lodgment to marine growths; but even glass itself is slowly acted upon by sea water, and when once roughened on the surface, will foul, while the rigidity of such coatings, and the straining and cracking consequent on unequal expansion and contraction of the plates and their coating, offers a serious obstacle to any such scheme.

In concluding this long paper, I wish to point out that in the present phase of the anti-fouling question, and until some new principle for preventing marine growth has been advanced and successfully adopted, satisfactory results can only be insured by an intelligent use of the existing compositions.

The protective composition is the important composition, and care must be taken to obtain the best in the market, as, if the protection is good, the plates remain uninjured even if fouling take place. The anti-fouling composition to be used with it must either be elastic or have the same rate of contraction and expansion as the protective, and must—at any rate in the navy—be chosen to suit the work to be done, such as contain copper compounds being carefully rejected, while preference should be given to those which rely on exfoliation rather than mineral poisons. If a vessel is to remain at rest for a considerable period, an anti-fouling composition which exfoliates rapidly, and which also contains poisons known to act on germ life, must be used, the amount of such poison depending on the seasons and the waters in which the ship is to be; while if a vessel is to be continually running, then a slowly exfoliating composition must be employed, and a very small percentage of poison is all that is required, as skin friction and the comparative absence of the germs and spores in deep water will do the rest.

Our ships represent an enormous capital, and any trouble or care which will prolong their existence is well worth taking and will be amply repaid, and at the present time a heavily corroded and foul vessel means either ignorance or negligence on the part of those who have the responsibility of deciding on the compositions to be used; and, finally, it must be clearly borne in mind that there is no anti-fouling composition which ever has been made, or probably ever will be made, that will answer for all cases, and that, until this is clearly recognized, the present unsatisfactory condition of the question will exist.

WOODEN PAVEMENTS IN PARIS.

MR. A. C. DANNER, the Mobile, Ala., lumberman, is deeply interested in the improvement of Mobile streets, and is doing a great deal toward making them not only passable, but substantial thoroughfares. In his investigations on the subject of wooden pavements, says the *Timberman*, he has received the following from the prefect of Paris:

PARIS, FRANCE, April 29.

SIR: By a letter dated March 13, 1889, you have asked me for information as to the use of wooden pavements in Paris.

Wooden pavements in Paris have had an incontestable success, due partly because it is better understood and the work better executed than in any other towns. The public appreciates it strongly, and the administration have come to the conclusion that the subject of paving no longer presents any difficulties. That which one appreciates in wooden pavement is its noiselessness to those who live along the public streets, and its evenness, and at the same time its elasticity, which renders the traction much easier, and the many advantages it possesses both for foot passengers as well as for horses and all vehicles.

On the other hand, wooden pavements require great care and assiduous cleansing, constant washing with water (nearly every morning it should be done on the most frequented streets), and sprinkled frequently with clean sand, according to the circumstances of the atmosphere, and unless this care is given to it, wooden pavements will give greater inconveniences than advantages. Asphalt possesses the same qualities as wooden pavement in regard to traffic, and has the advantage of being impermeable, and to require less care as to cleansing, but the public, with some exaggeration, perhaps, consider it more slippery.

The woods used are:

Pitch pine, for certain streets that have a great deal of traffic over them, being very hard, not at all slippery, and excellent wood for the purpose.

French pine, which has given very good results; the "double" or "twin" pine is nearly equivalent to pitch pine.

Swedish pine, which originally was used exclusively on account of its low cost, its homogeneousness, and on account of the vast extent of forests permitting the feasibility of obtaining as much as was needed, is now pretty much abandoned in place of the French pine, which affords better surface for walking, and is more resisting.

As a rule, these woods are not put down when the sap is in the tree, but generally in winter, or better still as regards the French pine, after the sap of August. However, some timber growers maintain that resinous wood can be cut down when the sap is in the tree. The question has not been elucidated by experience.

Chestnut has some special advantages. Beech has been used along the line of tramways, and has received very limited use. Larch has not yet been tried.

The durability of wooden pavements, according to the amount of traffic, and for a pavement well laid, will vary between seven to twelve years, but it is necessary at the beginning to be very strict as to the selection of the wood, and to be very careful afterward in the keeping in repair and the proper cleansing of the pavement.

The net first cost of a square meter of wooden pavement of 0·15° in height, including the foundation of concrete of 0·15°, but not including the removal of the old road, varies between 17f. and 19f. The cost of an asphalt road of 0·05° height upon concrete foundation of 0·15° is 19f. 50c. per square meter. The cost of a stone road upon a foundation of sand varies between 18f., 18f. 60c. and 23f. per square meter, and upon concrete between 20f. and 26f. per square meter. Of course it is understood that all these figures apply to Paris.

As to the annual expense connected with the pavement it can be calculated at from 20c. to 40c. for proper repairing, and between 80c. and 1f. 20c. for cleansing.

Receive my salutations, etc. General inspector of bridges, etc.

(Signed) V. MUES.

SEAMLESS boiler tubes are now made from solid ingots of metal by a process that twists and stretches the fibers, and is said to make a tube much stronger than the ordinary ones.

RADII OF CURVATURE GEOMETRICALLY DETERMINED.

By Prof. C. W. MACCORD, Sc.D.

XI. THE HYPERBOLA.

FOR a description of the apparatus for tracing the hyperbola by continuous motion, shown in Fig. 41, the reader is referred to SCIENTIFIC AMERICAN SUPPLEMENT, No. 530: it is reproduced here because by its aid the additional lines required for the graphic determination of the radius of curvature will be more readily understood.

Suppose for instance that we wish to find the center of curvature for the point P on the hyperbola. The normal at that point being perpendicular to I P T, is parallel to E I E; and this latter line has only a motion of rotation about the focus F. If then the apparatus be set in motion by turning the crank C I, at any assumed rate, we have to find first, the angular velocity of E I E, and second, the linear velocity of P, whose motion at the instant is in the direction T P T.

Let I L, perpendicular to C I, represent the linear velocity of the point I; this has a component I O in the direction I P T, and I F O represents the angular velocity of I about F.

Next, since F' G P is always parallel to C I, the angular velocities of those two lines about the fixed centers F' and C are equal; therefore P Q, perpendicular to P F' and limited by F' Q parallel to C L, is that component of P's motion which is due to its rotation about F'. But the resultant motion of P must be in the direction I P T; and its magnitude P S is determined by drawing Q S perpendicular to P Q.

Now, just as I is rotating about F, so P is rotating about the point of which we are in search, which lies upon the normal; and with the same angular velocity. Therefore, drawing through S a parallel to O F, the intersection of this line with the normal at P fixes U the center of curvature required. Should this intersection be inconveniently remote, the value of U P may be found by the proportion

I O : I F :: P S : radius of curvature.

In finding the radius of curvature at the vertex, it is to be noted that the points P and I will fall together at B, and their motions will coincide in the direction of the vertical line at that point. Let B H be the velocity of the crank pin I; then B N, determined by drawing F' N parallel to C H, will be the velocity of the pencil P, and B F H will represent the angular velocity of I about F; therefore a parallel to H F, drawn through N, will cut the line of the major axis at W, the center of curvature.

In this case we have

$$B H : B N :: B C : B F',$$

also

$$B H : B N :: B F : B W;$$

whence

$$B C : B F' :: B F : B W,$$

or

$$B W = \frac{B F \cdot B F'}{B C},$$

in accordance with the results of analysis.

The superiority of the above method to that of determining the motions of two points on the normal, in respect to simplicity and directness, will be apparent from a study of Fig. 42, in which the latter process is employed. The motion P S of the point P is determined as in Fig. 41, after which the instantaneous axis of the slotted bar is to be found; this is at the intersection J of the normal at P with the prolongation of the line of the crank C I. In order to find the motion of this point J, we have first a component of rotation about C; this component is J K perpendicular to C J, and limited by the prolongation of C L: supposing the normal momentarily at rest, this would give the intersection a motion J Y, determined by drawing through K a perpendicular to K J. Next, supposing the rotation of C J to cease for the instant, the normal has an actual motion of translation P S; but P is not receding from I at this rate, because I L, the actual motion of I, has a component I O in the same direction. Setting back S D = I O, then, and drawing through D a parallel to P J, cutting C I produced in Z, we have J Z for the second component of the motion required, which is J X the diagonal of the completed parallelogram Y J Z X. Of this resultant, the component perpendicular to the normal is J V; and finally drawing S V, and prolonging it to cut the normal P J produced in U, this last point is the center of curvature at P.

The above is the argument *in extenso*, as required in a general application of this process; but in this particular case, it may be of interest to note that the work may be very much abbreviated. For, observing that P J is parallel to I G and I J parallel to P G, we have P J equal to I G and therefore equal and parallel to I F; and since P I is perpendicular to both I F and P J, it follows that F J is perpendicular to P J: that is to say, the instantaneous axis of the tangent is the foot of the perpendicular from the focus upon the normal. Consequently V J produced passes through F; and for our purpose it would suffice, after locating S and D as previously explained, to draw through D a parallel to the normal, and through F a parallel to the tangent; these lines intersect in V, and we thus reach the goal by a much shorter route.

The same is true in dealing with the parabola; as by reference to Fig. 31 (see article IX. of this series, SCIENTIFIC AMERICAN SUPPLEMENT, No. 680), it will be apparent that H I produced passes through F, so that the construction last explained applies in that case also without change. But these are merely fortunate possibilities due to peculiarities of these curves, and are not in general to be hoped for.

FIG. 41.

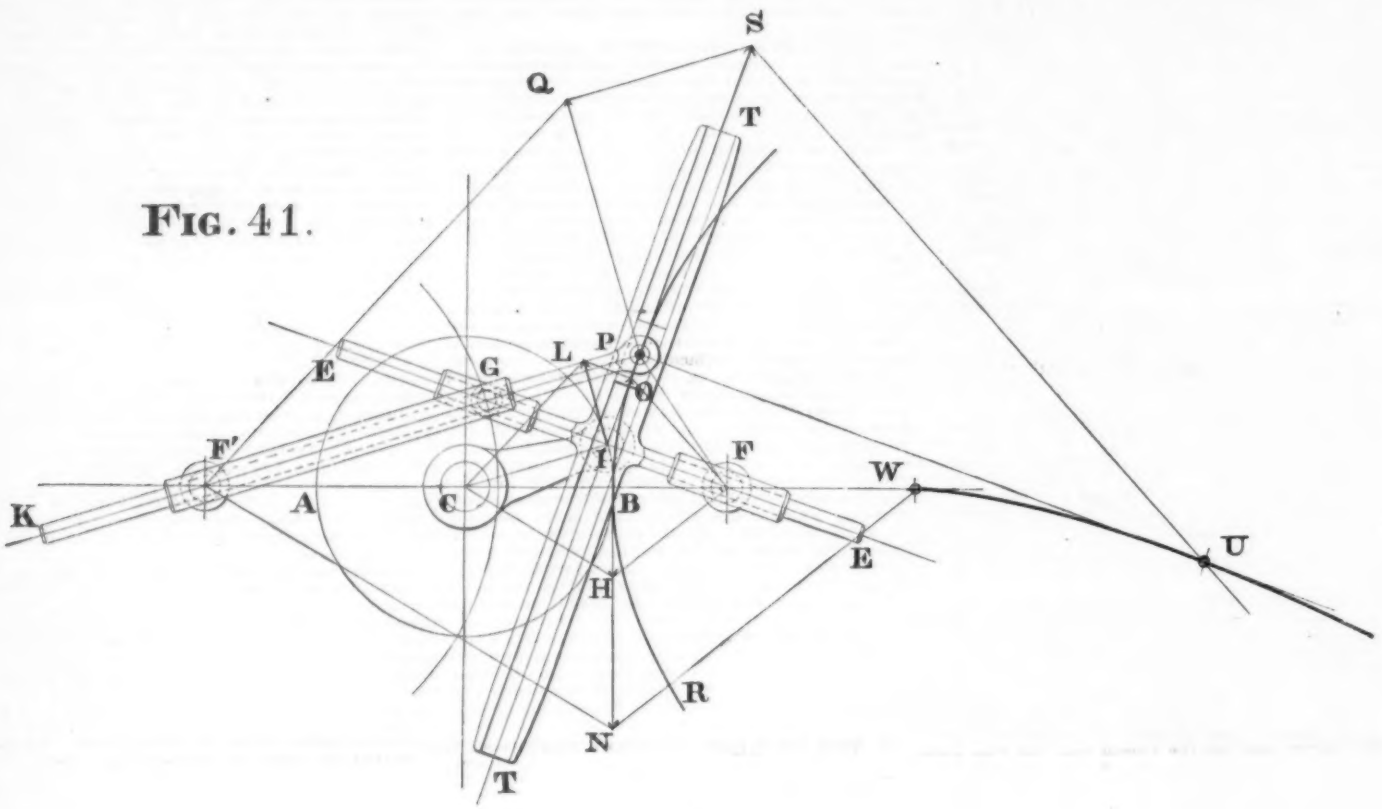
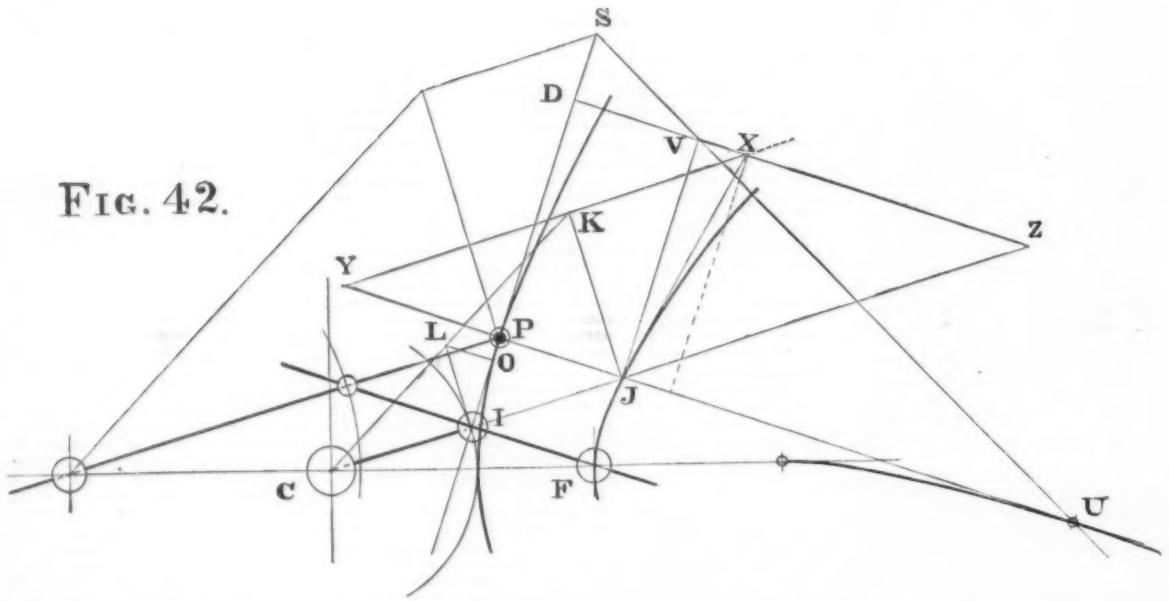


FIG. 42.



M. VICENTE SOLIS LEON says, in the *Revista de Merida*, that a new textile plant has lately been attracting some attention in Yucatan. The natives recognize it under the name of *xtuc*. The *xtuc* grows on the hillocks and in the waste grounds at Yucatan, which are called *cuyos*. The owner of the Xcanchacan *hacienda* has sent several pounds of *xtuc* fiber to a New York firm, which immediately gave an order for 2,000 bales, offering the price of fifteen cents per pound. The fiber, it appears, can be substituted for flax, or be mixed with linen yarn for the manufacture of fine tissues. The *xtuc* grows like the henequen (Sisal hemp). In growing, it successively loses its lower leaves, and forms a trunk which grows to a height of four meters and sends out branches in the manner of a tree. It produces, till its decay, several thousands of fibrous leaves, averaging 20 inches in length.

TRACTIVE FORCE OF LEATHER BELTS ON PULLEY FACES.*

By SCOTT A. SMITH, Providence, R. I.

IT is of the highest value to users of leather belts to know the exact conditions which give the greatest tractive force of belts on pulley faces; in immediate connection with this, it is essential to have knowledge of what constitutes the best leather belting.

It is the opinion of the writer that the best belts are made from all oak-tanned leather, and curried with the use of cod oil and tallow, all to be of superior quality. Such belts have continued in use thirty to forty years, when used as simple driving belts, driving a proper amount of power, and having had suitable care.

In the best methods of currying, only a very small quantity of the stearine of tallow enters into the leather; the oleine of the tallow and cod oil, during a period of four weeks employed in a suitable currying process, oxidize under the influence of heat, moisture, and much hand and machine labor intelligently used, and become or partake of the nature of a gum or varnish, most intimately united with fibers which interlace in all directions.

Such leather contains no free oil, which would, if of animal or vegetable origin, have a natural tendency to generate free acid injurious to the fibers. Belt leather thus made has a supple character, with a little elasticity and compressibility which eminently fits it for tractive used on a pulley face.

When a new belt is put to use with the flesh side to the pulley, there is on it a certain quantity of stearine from the tallow (rubbed down to give smoothness to that side); this grease acts, or aids, by increasing the surface of contact, to give an extra tractive quality to the leather. If the grain side is run to the pulley face, then, in the first use of the belt, there is more tendency to slip, owing to the absence of grease on the surface, and also to the fact that the grain is hard; and in the case of small diameters of pulleys, the belt face is wrinkled. Thus it is less in a condition to be brought into intimate contact, under pressure, with the pulley face, over its whole contact surface, than is the softer flesh side. The stearine on the surface of the flesh side and the softness of its face operate to exclude air from between the two surfaces, thus affording the benefit of atmospheric pressure, the strongest element in its tractive force, to hold the belt to the pulley face. In addition, when the two surfaces of leather and iron come together, on one or both of which there is a semi-fluid to interpenetrate into the pores of the two faces (provided there is a minimum of this material, or only sufficient for this interpenetration), then this material becomes an impediment to the slipping of the belt to the extent of the cohesion of its particles, to which is to be added much of its power of adhesion to, or affinity for, the iron and leather.

This statement, in relation to the action of stearine on the flesh side of leather, and the running of that side to a pulley face, is not given in the sense of an approval of either the one or the other, but to illustrate by a familiar fact. Stearine has no legitimate place on, or in, leather: also the flesh side should not be run to the pulley face, for the reason that the wear from contact with the pulley should come on the grain side, as that surface of the belt is much weaker in its tensile strength than the flesh side; also, as the grain is hard, it is more enduring for the wear of attrition; further, if the grain is actually worn off, then the belt may not suffer, in its integrity, from a ready tendency of the hard grain side to crack.

The most intimate contact of a belt with a pulley comes, first, in the smoothness of a pulley face, including freedom from ridges and hollows left by turning tools. Second: in the smoothness of the surface and evenness in the texture, or body, of a belt. Third: in having the crown of the driving and receiving pulleys exactly alike; as nearly so as is practicable, in a commercial sense. Fourth: in having the crown of pulleys not over $\frac{1}{2}''$ for a 24" face, that is to say, that the pulley is not to be over $\frac{1}{4}''$ larger in diameter in its center. Fifth: in having the crown other than two planes meeting at the center. Sixth: the use of any material on, or in, a belt, in addition to those necessarily used in the currying process, to keep them pliable or increase their tractive quality, should wholly depend upon the exigences arising in the use of belts; and the use of such material may justly be governed by this idea, that it is safer to sin in non-use than in over-use. Seventh: with reference to the lacing of belts, it seems to be a good practice to cut the ends to a concave shape by using a former, so that there may be a nearly uniform stress on the lacing through the center as compared with the edges. For a belt 10" wide, the center of each end should recede $\frac{1}{10}''$

An impediment to the just use of leather belting, in minor cases, comes from the fact that many manufacturers of machinery will adhere to the custom of putting too small receiving pulleys on to their machines, to indicate to the purchaser that little power is required to operate them. I have a feeling of pride in having the acquaintance of an eminently practical man who takes off a pulley 6" diameter by 4" face on a circular saw arbor and substitutes a pulley 9" diameter by 6" face.

A few words as to hemlock-tanned leather, or leather tanned by the use of half hemlock and half oak bark. I do not consider them as worthy of much consideration, as many makers of that class of belting stock have been obliged to abandon its manufacture during the past forty years. It is a less costly and less enduring product. It goes without saying that a well-made "hemlock" belt is better than a poorly made "oak" belt, duly considering all the processes involved in the making of each.

I would maintain that a skilled maker of oak-tanned belting can meet any and all legitimate requirements, whatever they may be. Some uses of a belt demand that it shall be much softer than for other purposes; some that it shall be elastic; other cases need a very rigid or non-elastic belt. For quarter-twist belts, owing to the firmness of oak-tanned leather, the belts should be specially shaped by the maker for that use, both in the length of the belt and at the ends.

Referring again to the subject of oils on leather: mineral oils always act to negative oxidation of the oils in the currying process; hence they are detrimental for that use. If added after the currying process is completed, then they tend to undo the currying by softening the oxidized oils.

A question not to be ignored relates to the action of air and other influences in keeping belts from full contact with the top side of a receiving pulley, when belts are run at very high speeds; this is caused by the massing of air at this point; by excessive crown in pulleys, giving much convexity to the belt, to hold air on or in its concave side; by the rigid character of many belts; and by centrifugal force.

Much leather belting is made which, when finished, has a very rigid character. It has gone into the hands of users in that condition for these reasons: First, because a desire has grown with some users to have belts extremely rigid against stretching—apparently forgetting that such rigidity insures that a belt shall have a comparatively short life. Second, to make a belt very supple and very uniform, in its body, and over its whole surface, necessitates expensive methods in currying. The continual demand for lower and lower prices has induced the leaving out of that amount of careful hand labor which always gives suppleness to leather, if otherwise well qualified; and in place of it has come a "machine" surface finish, which, to the eye, passes for the genuine article. This suppleness—sometimes called mellowness—gives to leather due pliability, and such belts run satisfactorily at high speeds.

While the "suppleness" of belt leather has been denominated "mellowness," it should be stated that there is a resistance to flexion, in the best leather, due to its components of fibers, interlaced in all directions, and a body of flexible gum, which, while it readily bends, yet it as readily returns to its initial shape; but the best is fully appreciated only through experience.

Rigid belts are sometimes made pliable by saturation with "belt oil," but the inevitable result, in time, is a disorganized belt; slipping will come; and the addition of more oil only results in its acting as a lubricant, by piling up on the surface.

There is some doubt in my mind as to the desirability of perforating belts, or the drilling of pulley faces, to overcome the difficulty mentioned, so far as it comes from the air, which is not so much a real difficulty when properly made belts are used as it is with rigid belts.

Free oils added to curried leather give "momentary" added strength by filling all the pores to distention, thus locking fibers to place; and by softening the fibers and allowing a strain—for instance, at lace holes—to be distributed over very many fibers.

As friction is due—largely—to the unevenness of two surfaces in contact under motion, and as the best tractive quality of belts comes from the evenness and smoothness of the two surfaces of belt and pulley face, it easily follows, from what I have said, that the value of the tractive force of a belt on a pulley face is due, first, to atmospheric pressure; second, to the tractive adhesion of the leather fibers and the oxidized oil of the currying process.*

* A paper read before the American Society of Mechanical Engineers, Erie, 1889.

* For a fuller understanding of all matters connected with leather belts I refer you to an article written by me, entitled "Leather: Reasons why Uncurried Leather has Little Strength, and the Cause of the Great Strength of Curried Leather," published in *Power-Steam* in July, 1887. Also to a paper read at Boston, in October, 1888, before the N. E. Cotton Manufacturers' Association—"Leather Belts: How to Determine the Relative Value of Different Makes."

ON THE SECURITY AGAINST DISTURBANCE OF SHIPS' COMPASSES BY ELECTRIC LIGHTING APPLIANCES.†

By Sir W. THOMSON.

THE danger to be avoided is sufficiently explained in the following short statement by Mr. William Bottomley, which appeared in the *Nautical Magazine* for December, 1885:

"The following example of a case which might occur in any large ship will show the amount of error which may be produced on the compass (by the electric lighting apparatus) unless precautions are taken to guard against it. Suppose a main lead from the engine room to the fore part of the ship, to light up one hundred lamps, is brought along the center of the ship. It may be at a distance of 10m., or 33ft., from the standard compass, and will run almost underneath it. If we suppose that each lamp takes one ampere of current, there will be a current of 100 amperes altogether in this lead. Now, the effect (of an infinitely long straight current) on the compass (above it) at a distance D in centimeters is given by the formula $F=(2\times\frac{1}{10}C)/HD$, where C is the current in amperes and H is the horizontal magnetic force. In this case we have C=100 amperes and D=1000cm. Therefore $F=20/1000H=0{\cdot}02/H$. At Glasgow the horizontal force may be taken as 0·15 in c.g.s. units, therefore the effect on the compass will be $0{\cdot}02/0{\cdot}15=1/7{\cdot}5$. This will be expressed in degrees by multiplying by 57·3, the number of degrees in the radian, or angle subtended at the center of a circle by an arc equal in length to the radius. Therefore, the amount of error produced by such a current on the compass will be $57{\cdot}3/7{\cdot}5=7{\cdot}6°$. The foregoing refers to a single wire and a continuous current machine; but if an alternate current machine is employed, no effect will be produced on the compass, even when the ship's side is used for the return. When a continuous current machine is used, the danger of producing an error on the compass can be avoided by using two wires close to one another, but these wires should be well insulated from the ship's side. If in any way (two points of) one of the wires is brought in contact with the iron of the ship, there may be no change observable in the lighting, but the current may produce as much error on the compass as it would if there was only a single wire. The following points should, therefore, be attended to in all cases of lighting ships by electricity: (1) With continuous current machines two wires well insulated should always be employed. (2) The insulation of the wires should be tested periodically; if any connection with the iron of the ship is found, the fault should at once be made right. (3) When an alternate current machine is used, a single wire may be employed and the iron of the ship used to complete the circuit without producing any effect on the compass. What makes this question of the greatest importance is that the error may be produced without ever being detected by the officers of the ship. On board ship the errors of the compass are usually determined during the day—in the morning and afternoon—but the electric light is only used at night. The captain may, therefore, carefully determine his errors every day, and set his course quite correctly; but at night, when the electric light is turned on, the ship may be going several degrees off her proper course, although she is being correctly steered by the compass. In connection with the lighting of ships with electricity, there is another point which should also be attended to—that is, the position of the dynamo. If it is placed near an iron bulkhead, the upper end of which is near the compass, the bulkhead may become magnetized by induction so powerfully that it will produce a considerable error on the compass."

The subject was also referred to in Mr. Bottomley's paper on "The Magnetism of Ships and the Mariner's Compass," read before the Society of Arts, January 28, 1886, and published in the *Journal* of the Society for February 5, 1886. In the discussion which followed and in which Captain Creak, of the Admiralty compass department, Mr. Alexander Siemens, and Dr. Hopkinson took part, it appeared that in three ships, lighted on the single wire system with direct currents, small but not unimportant errors in the compass, due to the lighting currents, had been actually observed. Since that time several cases have been reported to me of large passenger ships, lighted with direct currents on the one-wire system, in which as much as 4° or 5° of error on the compass has been produced by the electric lighting. In the latest of these cases, a few weeks ago, an error of 4° on the north course was found when the light was put on. The light was put on and off several times with the ship's head north, and every time the same error was produced.

The precautions for security which I have to suggest are:

(1) The use of the two-wire method exclusively (unless, which is now rarely the case, alternate currents are used).

(2) A differential galvanometer on the two mains for the lighting current to show approximate enough equality of the outgoing and incoming current. A rough and cheap instrument (on the old telegraph "detector" plan) would, I believe, suffice, and would be valuable for the electric lighting system (independently of the compass question) to give timely warning of any faults or accidental contacts or failures of insulation sufficient to cause any considerable difference in the strength of the currents carried by the two mains.

(3) Care that there is not magnetic "leakage" from the dynamo (as practical men, guided by Faraday's ideas, theory, and language, have now taught the scientific world to call it) enough to produce any compass disturbance of practical moment. Captain Creak, speaking at the beginning of 1886, in the Society of Arts discussion previously referred to, said that in one ship the direct compass disturbance produced by the generating machine was "felt through a distance of 55 ft.," and across iron bulkheads, and that it was perceptible also in other ships of the royal navy electrically lighted on the two-wire system. My impression is that the improved dynamos now made have much less of magnetic leakage than those made prior to 1886, but we still want information as to their disturbing magnetic effect at such distances as have to be considered in connection with the compass question.

(4) To ascertain that there is no perceptible compass disturbance, or if there is any to test its amount, the compass should be observed while the current through the dynamo is started and stopped, either by starting and stopping the dynamo itself, or by making and breaking the circuit of the field magnets. This should always be done before the electric light installation is taken over from the contractors. It is best and most easily done when the ship is in dock, or lying steadily at anchor. On no account ought it to be delayed in a new ship till she goes out for compass adjustment. A determination of the amounts of the disturbance, if any, for all courses of the ship can be made by aid of my deflector without moving the ship. But a sufficient practical test may be made by first observing the effect of starting and stopping the current on the compass as it stands; then adjusting a small magnet placed on or supported a little above the glass of the bowl, to deflect the compass about 45° first on one side and then on the other side of its undisturbed position, and in each case observing the effect of starting and stopping the electric current. This effect ought not to be as much as 2° in any of the three cases.

(5) A small electric lamp may safely (and with very great advantage in most cases of electrically lighted ships) be used to light the compass. The effect, if any is perceptible, of its current on the compass ought to be tested in the manner described in No. 4. Those who know the trouble of keeping the best of ordinary compass lamps alight, for the steering compass on the bridge of some of our cross-channel steamers in a winter gale, will appreciate this advantage.

In opening the discussion, Captain Creak said he was glad Sir William recommended the two-wire system, for that in itself was a great safeguard against disturbance. So far as his own experience showed, the most trouble arose from magnetic leakage, due to the employment of machines having a considerable external field, especially if the machines be so placed that this field was directed toward the compass. In one case (H. M. S. Northampton), where three such machines were used, an error of 11° was produced when all the machines were running, and three correction tables were necessary.

Mr. Alex. Siemens, as an advocate of the single wire system, thought it quite unnecessary to use two wires, for in all his experience, extending over many ships fitted on the single wire system, only one instance had occurred in which complaint was made, and in this case the wiring was done before the position of the compass had been decided upon. His firm make inquiries on all vessels fitted by them every time they come into port, in order to ascertain whether any inconvenience arises from the electric lighting apparatus, but with the exception above quoted no complaint had been made. Referring to Mr. Bottomley's letter mentioned in the paper, Mr. Siemens said the screening effects of the decks had been entirely neglected in the calculations there given. A second case of disturbance had come under his notice when he was asked to in-

† Paper read before the Institution of Electrical Engineers, May 23, 1889, by Sir W. Thomson, president.

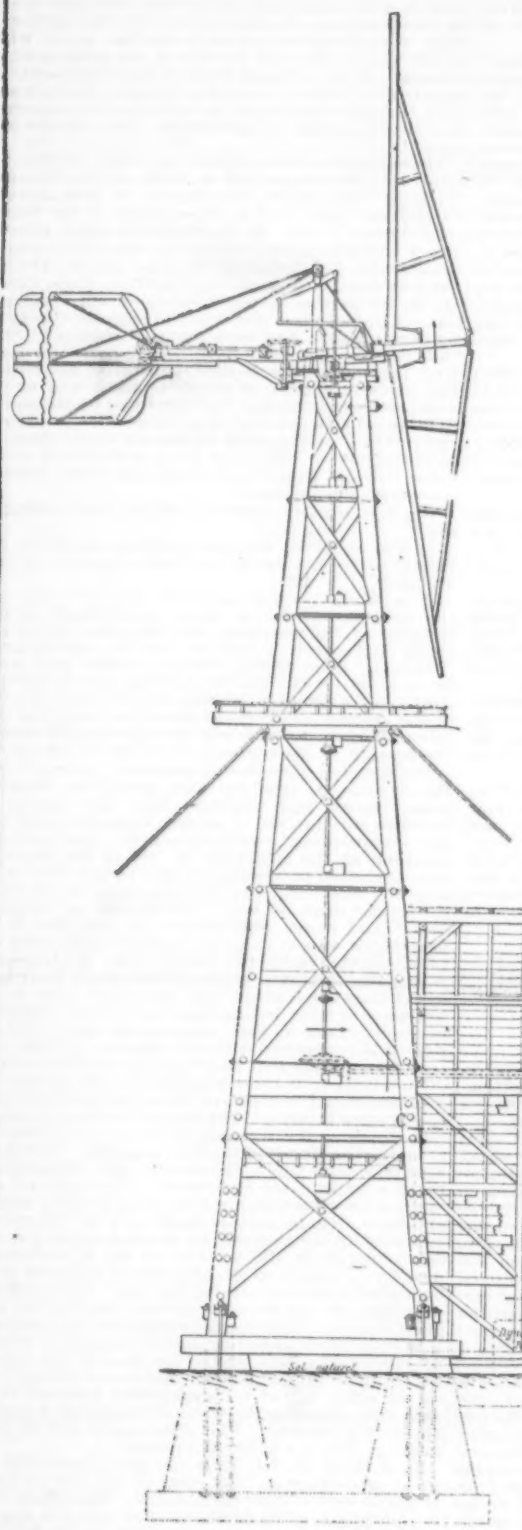


Fig. 1.—Coupe longitudinale suivant AB (échelle 0m,033 p. 1m.)

Fig. 4.—Elévation de face (échelle 0m,033 p. 1m.)

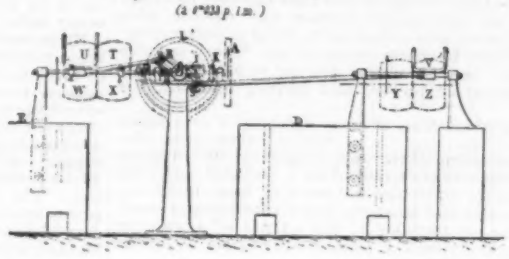


Fig. 5.—Plan (échelle 0m,033 p. 1m.)

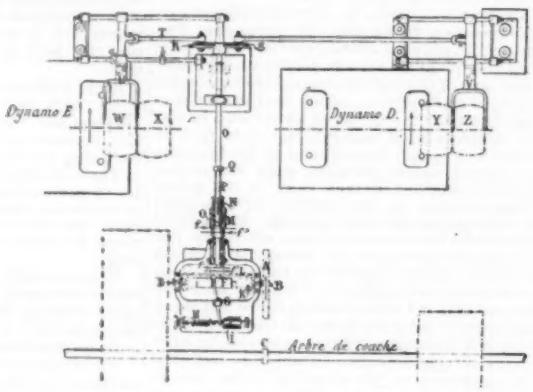


Fig. 3.—Coupe transversale EF

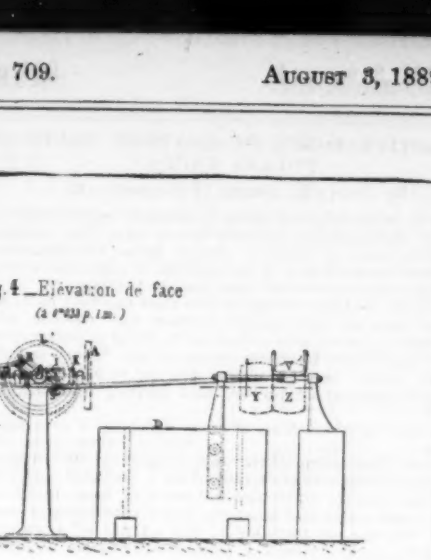


Fig. 6.—Vue de côté (échelle 0m,033 p. 1m.)

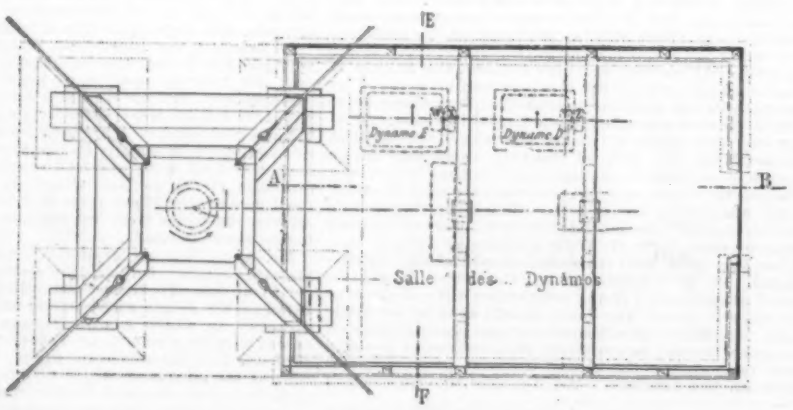
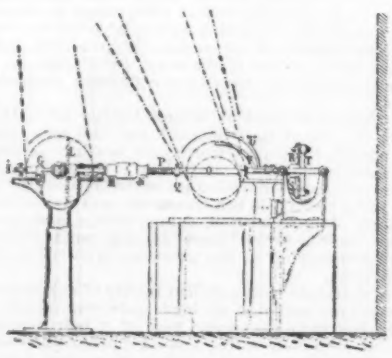


Fig. 2.—Plan suivant CD (échelle 0m,033 p. 1m.)



WINDMILL FOR PRODUCING ELECTRIC LIGHT.

spect a ship fitted by another firm, and the maximum deflections produced were ¼° and 1½° on the standard and steering compasses respectively. As regards the position of dynamos, he had found no appreciable effect at distances greater than 50 ft.

Professor G. Forbes, speaking of H. M. S. Northampton, said that the dynamos referred to by Captain Creak were placed in an iron room, and still the disturbance produced was very serious. From an examination of machines of the type there employed, he found that the leakage mainly came from the parts of the yokes near their junction with the cores, but he had reason to believe that in the more modern machines the leakage had been considerably reduced.

Professor Jamieson mentioned the case of the ss. Bombay, in which the steering compass was disturbed 9°. The fault was traced to a wire about 4 ft. from the compass, and remedied by running a return wire close to it.

Mr. Raworth, in corroborating Mr. Siemens with regard to the great convenience of the single wire system, gave additional details respecting the second case of disturbance mentioned by Mr. Siemens. The compass was influenced by either of two conveying wires running along lower passages, according as the needle was parallel to one or to the other. On examining the decks, the iron was found cut away between the wires and the needle, and the defect was remedied by inclosing the wires in 3 in. iron pipes.

Major Cardew described his experience in lighting binnacles electrically, as suggested by Sir W. Thomson in his note, and although he carefully twisted the leading wires together, the current through the filament seriously affected the compass readings.

Sir W. Thomson, in reply, said that caution was necessary in arranging lamps for lighting compasses, and in answer to Professor Forbes expressed the opinion that alternate currents, if used in such lamps, would not demagnetize the needles. Referring to the screening effect of decks, he pointed out that Captain Creak's observations proved them to be of little use in neutralizing the external field of dynamos. To be efficient for such a purpose, the iron room in which the dynamo was placed would have to be made with very thick walls. The decks may, however, considerably reduce the actions of currents on the compasses, especially where the circuits are completed between two decks; but when the wires pass from one deck to another, the screening effect is much reduced. Although the conductors in the single wire system may be placed so as not to affect either one of the two compasses generally used, yet it is very difficult to arrange that neither is disturbed, and as any disagreement between the two (especially as the difference may vary with the position of the ship) further complicates the navigation, Sir William felt sure it would be far the best plan to adopt the two-wire system in all cases.

WINDMILL FOR PRODUCING ELECTRIC LIGHT AT CAPE DE LA HEVE.

THE great principle enunciated by Lavoisier a century ago, that "nothing is lost and nothing created in nature," is true in electricity as elsewhere. Everything becomes merely transformed.

The idea of utilizing the natural forces for actuating dynamo-electric machines capable of producing electric light or mechanical force, or of storing up electric energy in accumulators, is, on another hand, too seductive to be new.

The wind, the movement of the tides, and waterfalls have successively attracted the attention of inventors, and experiments in this direction have even been tried in certain parts of England, Switzerland, and the United States.

It is to the imperfection of hydraulic receivers of large size that we think must be attributed the non-utilization of large waterfalls, of strong currents, and of important tides, up to the present at least. As for the wind, its irregularity has doubtless, up to the experiments that we are to speak of, caused innovation in the way of its industrial utilization to hesitate. The utilization of the force of the wind dates back to the middle ages. The first windmills, employed for raising water or grinding grain, made their appearance before the twelfth century. For drainage work, we find them in Egypt and Holland at epochs nearer our own. In agricultural exploitations and on railroads, they are found by hundreds in the United States.

The idea of charging electric accumulators by wind has been current for a long time in the scientific public domain. It was in July, 1886, that a wealthy landowner of the Cotes-du-Nord, Mr. Charles de Goyon, Duc de Feltre, was led to take up this question, which had much interested him. The duke's idea was to set up a self-directing wind motor that should actuate an electric apparatus for the production of a force that should be stored in accumulators, and to put this force at the disposal of small landowners and cultivators at a certain price. The idea was a good one, but was not very practical.

Electric accumulators are, as yet, heavy apparatus, of inconvenient carriage, and, on another hand, very delicate. However, the idea of the possibility of charging accumulators by the initial force of the wind remained entire. The *object* of operation was to change, that was all, for the duke thought almost immediately of the lighting of lighthouses by this method.

Engineer Beaumanoir, having had his attention directed to the subject, conceived the project of trying some experiments in this direction at the Havre exhibition. The proposition made by him to Mr. Bourdelles, superintendent of the lighthouse service, was favorably received, and early in 1887 he was authorized by the minister of public works to set up apparatus at Cape de la Heve for the purpose of lighting the northern lighthouse of that promontory.

The wind motor to be adopted had to be automatic and able to withstand tempests, and to develop a great power when required, and yet be capable of moving under light breezes.

The American mills seemed capable of realizing this programme, and, after an examination of several makes of these, it was decided to select Haladay's for the experiment.

The Haladay mill set up at Cape de la Heve is the size No. 12. The various views of the apparatus here given make it unnecessary to enter into details concerning it. The mill is mounted upon a solid and elegant wooden frame established upon a masonry foundation. The advantages that this motor possesses over others of its class reside in the facility with which it directs itself through a play of wheels interposed between the fixed and revolving disks and in a centrifugal force regulating system. The mill in question came directly from the United States. It gives motion through the intermedium of a vertical shaft and two pair of bevel wheels to a horizontal shaft placed at a proper height above ground. Upon this horizontal shaft are mounted the pulleys which, through belts, actuate the dynamos, the number and peculiarities of which will be given further along. The terminals of the dynamos are connected by a circuit with a series of accumulators in which is stored up the energy of the current produced by these machines. The question of the selection of appropriate dynamos was no less delicate than that of the selection of a motor. After a thorough consideration of the subject, the apparatus selected was the Brush dynamo of the type styled "Victoria."

The two Victoria dynamos furnished by the manufacturers are slow-running ones and thus do not necessitate too large a number of transmissions between their pulleys and the main shaft of the installation. Both of them, with variable velocities, furnish a current of which the difference of potential, measured at the terminals, is (when once the magnetic field is formed) constant and of 75 volts. The mechanical rendering is from 1 to 4 horses for the smaller and from 4 to 16 for the larger. The operation of these dynamos, then, is analogous to that of the lift pump connected with the mill, and this is the most judicious utilization of the variable power of the wind. The pump, in fact, lifts the water always to the same height (constant difference of potential); but it lifts a volume which varies with the mill's velocity, that is to say, with the variable motive power furnished by the wind (variable intensity). In theory, one dynamo of constant electro-motive force producing a current for an intensity proportional to the motive power collected by the mill, would have sufficed. In practice, it would have happened that such a machine would not only have been too costly, but also imperfect as regards performance, that is to say, as regards the ratio between the electric energy produced and the mechanical work that would be furnished to it. It was for this reason that two dynamos were adopted for the experiment. The smaller has a constant electro-motive force of 75 volts, with velocities of the ring varying from 100 to 260 revolutions per minute, and a constant intensity of 8 amperes at 100 revolutions and 40 at 260 revolutions. The larger has a constant electro-motive force of 75 volts, with velocities of the ring varying from 250 to 650 revolutions, and an intensity varying from 40 to 160 amperes. The two machines work alternately, according to the motive power furnished by the mill.

As regards the charging of the accumulators, it is not necessary that the stored-up electricity shall be able at any moment to return to either of the dynamos.

Therefore, between each dynamo and the series of accumulators under charge, there is established an interrupter or circuit cutter which isolates the accumulators from the dynamo when, for any cause, the electro-motive power of the machine falls below its normal value. This interrupter automatically re-establishes the communication between the dynamo and the accumulators as soon as the electro-motive power of the machine returns to its normal value.

As each dynamo is provided with a special regulator which keeps the electro-motive power constant, and regulates the intensity of the current according to the velocity, the intensity corresponding to a given velocity is thus connected with the electro-motive force; so that if, for example, we take the figures indicated above, the interrupter of the small dynamo will cut the circuit when the intensity of the current descends below 8 amperes, while that of the large one will cut the circuit when the intensity descends below 40 amperes.

The automatic engaging and disengaging regulator of the two dynamos is represented in Figs. 4 and 5. A is a pulley keyed to a horizontal shaft, B, and set in motion, always in the same direction, by a belt coming from a pulley, C, keyed upon the main shaft. F is a double coupling box which can slide on the shaft, B, which latter carries it along through a fixed key adjusted upon the shaft and a slot formed in the box. At the center the box is provided with a groove in which engage the two branches of a fork that forms part of a horizontal lever that oscillates around the point, G. The other arm of the lever is connected (1) with a spiral spring, H, whose tension can be regulated at will, and (2) with the cylinder, I, of a piston solenoid into which passes a derivation from the current issuing from each of the dynamos. When the main current reaches the maximum number of amperes fixed for the small dynamo, the solenoid acts upon the lever, which then takes the position shown in the figure and shoves the clutch, F, to the left. When the main current descends below such maximum, the spring acts upon the lever and pushes the clutch, F, to the right.

Upon the horizontal shaft, B, are mounted two loose pinions, J and K, the centers of each of which form half of a coupling box. If the solenoid acts upon the box, F, the latter gears with the pinion, J, and revolves the toothed wheel, L, in the direction shown by the arrow, *f*. If, on the contrary, the spring acts upon the clutch, F, the latter gears with the pinion, K, which revolves the wheel in the direction shown by the arrow, *f'*.

The toothed wheel, *h*, is keyed upon a horizontal shaft which, at its other extremity, carries half of a coupling clutch, M, the other half, N, of which is mounted upon a horizontal shaft, O, which is free in the interior of the half-clutch, M. The half, N, is pushed against the other by a spiral spring, P, the tension of which is regulated by means of a ring, Q, provided with a pressure screw. When the two halves, M and N, have entered one another, the shaft, O, participates in the revolution of the wheel, L, either in the direction shown by the arrow, *f*, or in that shown by *f'*.

At the extremity opposite the half-clutch, M, the shaft, O, carries two slotted arms, R and S, diametrically opposite each other. In R is mounted a slide to which is jointed a coupling rod, T, connected with a fork, U, that runs upon guides and embraces the belt that commands the large dynamo, E. The arm, S, is arranged in the same manner, and the fork, V, on the side with it embraces the belt of the small dynamo, D.

W is the fixed pulley of the dynamo, E, and X is its loose pulley. Y is the fixed pulley of the dynamo, D, and Z is its loose one. The arms, R and S, are therefore so arranged that the dynamo, E, is in gear while the other is out of gear, and *vice versa*.

The figure shows the cam through which the solenoid acts upon the clutch, F, and represents the dynamo in gear, that is in motion, and the dynamo, D, thrown out of gear.

The travel of the forks, U and V, is fixed by the positions of the slides in the arms, R and S. Their motion in each direction is limited by two rings, *a* and *b*, mounted upon one of the guides of one of the forks, and provided with pressure screws. In the figure, it is the fork, U, that is abutting now against *a* and now against *b*. As the shaft, B, is constantly revolving, and the wheel, L, is always commanded by one of the pinions, J and K, there would be danger of one of the parts of the regulator getting broken, or of a sliding of the belt upon the pulley, A, when the forks, U and V, are at the end of their travel. Such danger is avoided by giving the teeth of the two half-clutches, M and N, an inclination such that, under the effect of an abnormal resistance due to the abutting of the fork, U, against one or the other of its stops, the half-clutch, N, slides upon the shaft, O, compresses the spring, P, and thus escapes the action of M, which continues to revolve in front of N, without causing the shaft to revolve.

All the *materiel* here described is now mounted, registering apparatus have been added, and the experiments that are being made augur well for the complete success of the installment.—*Abstract from Annales Industrielles.*

ON THE INFLUENCE OF GAS AND WATER PIPES IN DETERMINING THE DIRECTION OF A DISCHARGE OF LIGHTNING.*

By HENRY WILDE.

ALTHOUGH the invention of the lightning conductor is one of the noblest applications of science to the wants of man, and its utility has been established in all parts of the world by the experience of more than a century, yet a sufficient number of instances are recorded of damage done by lightning to buildings armed with conductors to produce in the minds of some an impression that the protective influence of lightning conductors is of but questionable value.

The destruction by fire of the beautiful church at Crumpsall, near Manchester, during a thunderstorm on the morning of the 4th of June, has induced me to bring before the society, with a view to their being known as widely as possible, some facts connected with the electric discharge which have guided me for some years in the recommendation of means by which disasters of this kind may be averted.

For the proper consideration of this subject, it is necessary to make a distinction between the mechanical damage which is the direct effect of the lightning stroke and the damage caused indirectly by the firing of inflammable materials which happen to be in the line of discharge.

Instances of mechanical injury to buildings not provided with conductors are still sufficiently numerous to illustrate the terrific force of the lightning stroke and at the same time the ignorance and indifference which prevail in some quarters with respect to the means of averting such disasters; for wherever lofty buildings are furnished with conductors from the summit to the base and thence into the earth, damage of the mechanical kind is now happily unknown.

Even in those cases where lightning conductors have not extended continuously through the whole height of a building, or where the lower extremity of the conductor has, from any cause, terminated abruptly at the base of the building, the severity of the stroke has been greatly mitigated, the damage being limited in many cases to the loosening of a few stones or bricks.

The ever-extending introduction of gas and water pipes into the interior of buildings armed with lightning conductors has, however, greatly altered the character of the protection which they formerly afforded; and the conviction has been long forced upon me that, while buildings so armed are effectually protected from injury of the mechanical kind, they are more subject to damage by fire.

The proximity of lightning conductors to gas and water mains, as an element of danger, has not yet, so far as I know, engaged the attention of electricians; and it was first brought under my notice at Oldham in 1861, by witnessing the effects of a lightning discharge from the end of a length of iron wire rope, which had been fixed near to the top of a tall factory chimney, for the purpose of supporting a long length of telegraph wire. The chimney was provided with a copper lightning conductor terminating in the ground in the usual manner.

In close proximity to the conductor, and parallel with it, the wire rope descended, from near the top of the chimney, for a distance of 100 feet, and was finally secured to an iron bolt inserted in the chimney about ten feet from the ground. During a thunderstorm which occurred soon after the telegraph wire was fixed, the lightning descended the wire rope, and, instead of discharging itself upon the neighboring lightning conductor, darted through the air for a distance of sixteen feet to a gas meter in the cellar of an adjoining cotton warehouse, where it fused the lead pipe connections and ignited the gas. That the discharge had really passed between the end of the wire rope and the lead pipe connections was abundantly evident from the marks made on the chimney by the fusion and volatilization at the end of the wire rope and by the fusion of the lead pipe. As the accident occurred in the daytime, the fire was soon detected and promptly extinguished.

Another and equally instructive instance of the inductive influence of gas pipes in determining the direction of the lightning discharge occurred in the summer of 1868 at St. Paul's Church, Kersal Moor, during divine service. To the outside of the spire and tower of this church a copper lightning conductor was fixed, the lower extremity of which was extended under the

* From the Proceedings of the Literary and Philosophical Society of Manchester, January 9, 1872.

soil for a distance of about twenty feet. The lightning descended this conductor, but, instead of passing into the earth by the path provided for it, struck through the side of the tower to a small gas pipe fixed to the inner wall. The point at which the lightning left the conductor was about five feet above the level of the ground, and the thickness of the wall pierced was about four feet; but beyond the fracture of one of the outer stones of the wall and the shattering of the plaster near the gas pipe, the building sustained no injury.

That the direction of the electric discharge had in this case been determined by the gas pipes which passed under the floor of the church was evident from the fact that the watches of several members of the congregation who were seated in the vicinity of the gas mains were so strongly magnetized as to be rendered unserviceable.

The church at Crumpsall is about a mile distant from that at Kersal Moor, and the ignition of the gas by lightning, which undoubtedly caused its destruction, is not so distinctly traceable as it is in other cases which have come under my observation, because the evidences of the passage of the electric discharge have been obliterated by the fire. From information, however, communicated to me by the clerk in charge of the building, as to the arrangement of the gas pipes, the most probable course of the electric discharge was ultimately found.

The church is provided with a copper lightning conductor, which descends outside the spire and tower as far as the level of the roof. The conductor then enters a large iron down spout, and is carried into the same drain as that in which the spout discharges itself. Immediately under the roof of the nave and against the wall a line of iron gas pipe extended parallel with the horizontal lead gutter which conveyed the water from the roof to the iron spout in which the conductor was inclosed. This line of gas piping, though not in use for some time previous to the fire, was in contact with the pipes connected with the meter in the vestry, where the fire originated, and was not more than three feet distant from the lead gutter on the roof. As no indications of the electric discharge having taken place through the masonry were found, as in the case of the church at Kersal Moor, it seems highly probable that the lightning left the conductor at the point where the latter entered the iron spout, and by traversing the space between the leaden gutter and the line of gas piping in the roof found a more easy path to the earth by the gas mains than was provided for it in the drain.

In my experiments on the electrical condition of the terrestrial globe* I have already directed attention to the powerful influence which lines of metal, extended in contact with moist ground, exercise in promoting the discharge of electric currents of comparatively low tension into the earth's substance, and also that the amount of the discharge from an electrometer into the earth increases conjointly with the tension of the current and the length of the conductor extended in contact with the earth. It is not, therefore, surprising that atmospheric electricity, of a tension sufficient to strike through a stratum of air several hundred yards thick, should find an easier path to the earth by leaping from a lightning conductor through a few feet of air or stone to a great system of gas and water mains, extending in large towns for miles, than by the short line of metal extended in the ground which forms the usual termination of a lightning conductor.

It deserves to be noticed that in the cases of lightning discharge which I have cited the lightning conductors acted efficiently in protecting the buildings from damage of a mechanical nature, the trifling injury to the church tower at Kersal Moore being directly attributable to the presence of the gas pipe in proximity to the conductor. Nor would there have been any danger from fire by the ignition of the gas if all the pipes used in the interior of the buildings had been made of iron or brass instead of lead; for all the cases of the ignition of gas by lightning which have come under my observation have been brought about by the fusion of lead pipes, in the line of discharge. The substitution of brass and iron, wherever lead is used in the construction of gas apparatus, would however be attended with great inconvenience and expense, and moreover would not avert other dangers incident to the disruptive discharge from the conductor to the gas and water pipes within a building. I have therefore recommended that in all cases where lightning conductors are attached to buildings fitted up with gas and water pipes, the lower extremity of the lightning conductor should be bound in good metallic contact with one or other of such pipes outside the building. By attending to this precaution the disruptive discharge between the lightning conductor and the gas and water pipes is prevented, and the fusible metal pipes in the interior of the building are placed out of the influence of the lightning discharge.

Objections have been raised by some corporations to the establishment of metallic connection between lightning conductors and gas mains on the ground that damage might arise from ignition and explosion. These objections are most irrational, as gas will not ignite and explode unless mixed with atmospheric air, and the passage of lightning along continuous metallic conductors will not ignite gas even when mixed with air. Moreover, in every case of the ignition of gas by lightning, the discharge is actually transmitted along the mains, such objections notwithstanding. A grave responsibility therefore rests upon those who, after introducing a source of danger into a building, raise obstacles to the adoption of measures for averting this danger.

* *Philosophical Magazine*, August, 1888.

[Continued from Supplement, No. 708, page 11308.]

SIBLEY COLLEGE LECTURES.—1888–89.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

VI.—Some Applications of Electric Transmission.

By Frank J. Sprague.

I will consider then this main and working conductor system alone and how the current can be taken from the trolley wire. It is evident that such a wire is put up in a series of chords, and that at curves and sidings this wire does not follow the center line of the tracks, but on the contrary, if the supports are few in number, it may deviate from this center line three or four feet either way. It is evident likewise that the height of this line is variable. Ordinary demands require us to go about nineteen feet above the street, and yet we may have to pass under a bridge not over twelve feet high and take a railroad crossing of twenty-one feet. We must likewise be able to run in either direction.

These necessities have required us to develop a great many forms of trolleys, most of the successful

VIEW OF ELECTRIC CAR PASSING UNDER A BRIDGE ON STEUBENVILLE, O., STREET RAILWAY, SHOWING THE WIDE RANGE OF MOVEMENT AND FLEXIBILITY OF TROLLEY ARM.

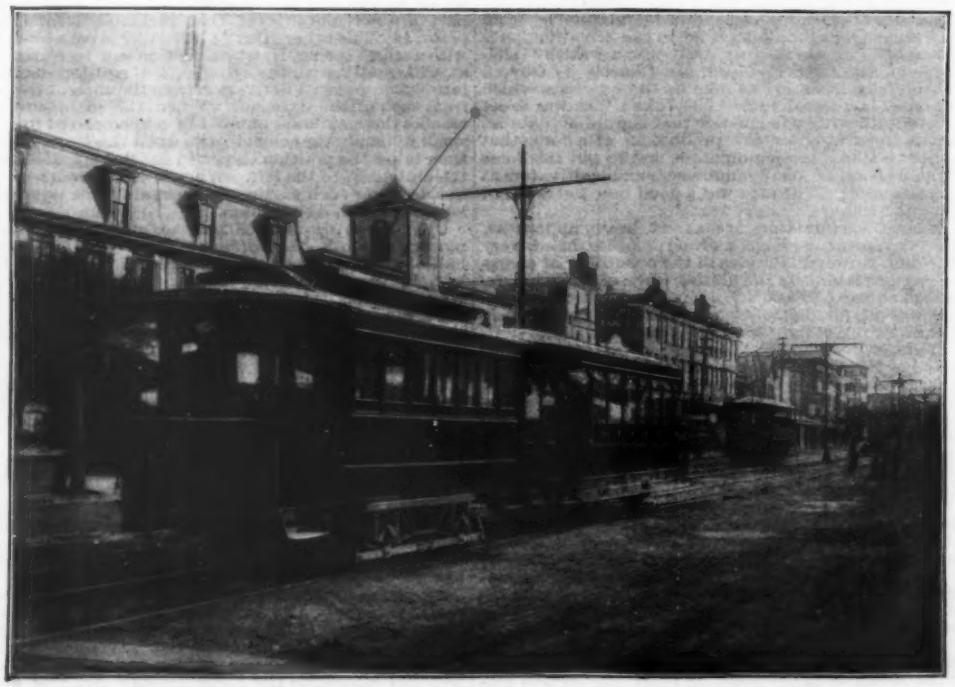
ones, however, belonging to one of two general classes. In the first the trolley pole when off the line is normally vertical, and either by a spring or a weight resists deflection in any direction from their position. In some forms this resistance to deflection is equal in any direction. In others, the resistance is greater to fore and aft deflection than to lateral, but is always equal in opposite direction. This is evidently as it should be, to prevent swaying of the trolley line by undue side pressure and to allow equal facility of running in either direction. When you consider that a heavy trolley on the end of a iron arm twelve feet long must be kept in intimate and constant running contact with a wire varying in height from twelve to twenty-one feet, and in a lateral direction about seven feet, some idea of the lively character of the spring which supports this contact pole at its heel can be imagined. This is the form which I prefer and which we now use. In another form, such as we use at Richmond, a normally inclined pole is carried on a center trunnion in a frame on top of the car, and is free to completely swing around this trunnion. This is a very effective arrangement, and has done us very good service, but has not the quality of automatic reversal of inclination in case of necessity, or such a great range of deflection, as the form which I described a few moments ago.

One of the most curious things to contemplate is the exceedingly small time of contact and its apparent frailty. This has an important bearing on the life of a conductor. When a trolley wheel contact is used, this contact, being that of a rounded surface against a cylinder a quarter of an inch in diameter, is hardly more than that of a line. Suppose that the yield of the line makes it an eighth of an inch in length, and further suppose that the cars make an average speed of eight miles an hour on five minutes headway and on a double track. In such case different portions of the line are in contact with the trolley wheel an average of $\frac{1}{237555}$ of the time. The actual period of contact of any portion is $\frac{1}{11111}$ of a second, and on a sixteen hours' schedule, an aggregate of about one second in six days, or a minute in a year. Through this flying contact comes the energy which is controlled, and when the line is clear and the contact arm well supported, not a sign of the passage is seen on the darkest night, even when making twenty-five miles an hour, and with the contact period reduced to nearly $\frac{1}{37500}$ of a second.

Even if the contact is too light and sparking occurs, the contact of the moving trolley does not remain long enough to burn the trolley wire. To guard against this kind of burning, and against the possible wear, we connect the generators to line, so as to make the current pass from the trolley to the wire.

One of the most vital questions in street railway work is that of the method of mounting the motors and how the motion of the armature shall be transmitted to the car axle. We find car bodies of various patterns but similar in character mounted on independent springs, which are in turn supported by independently moving axles. The resilience of these springs must be undisturbed. The largest amount of space must be reserved for passengers.

There must be as little disturbance as possible of the general arrangement of parts, yet at first sight all the

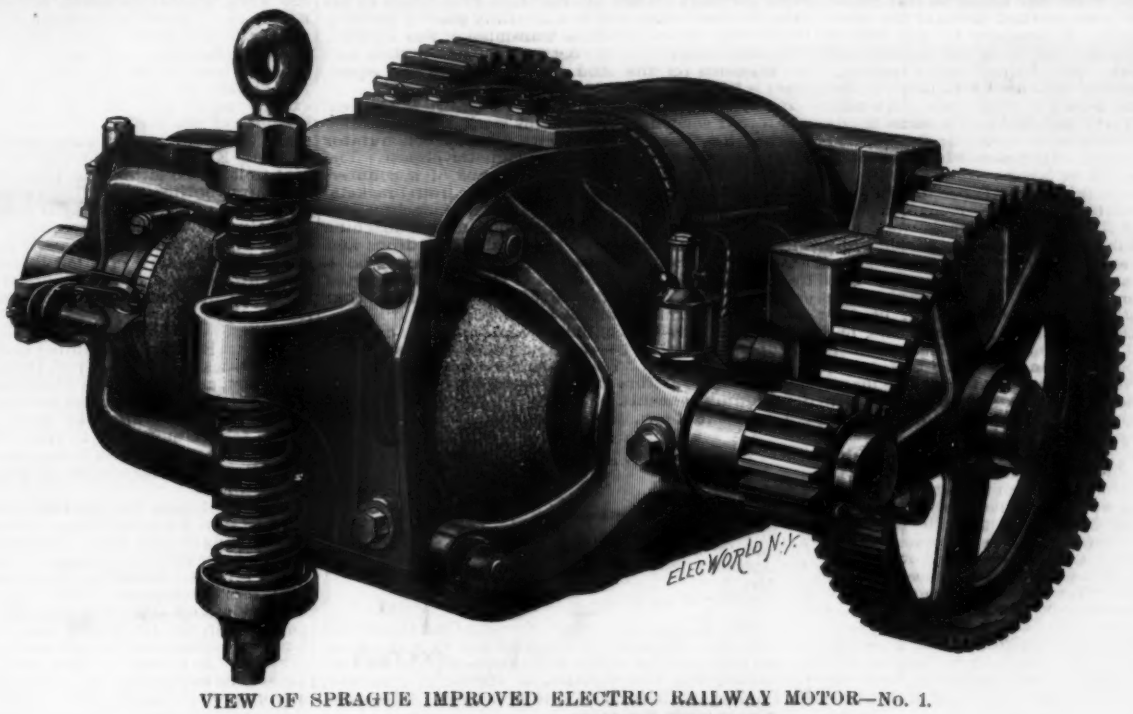


VIEW OF ELECTRIC CAR IN OPERATION AT ATLANTIC CITY, N. J.

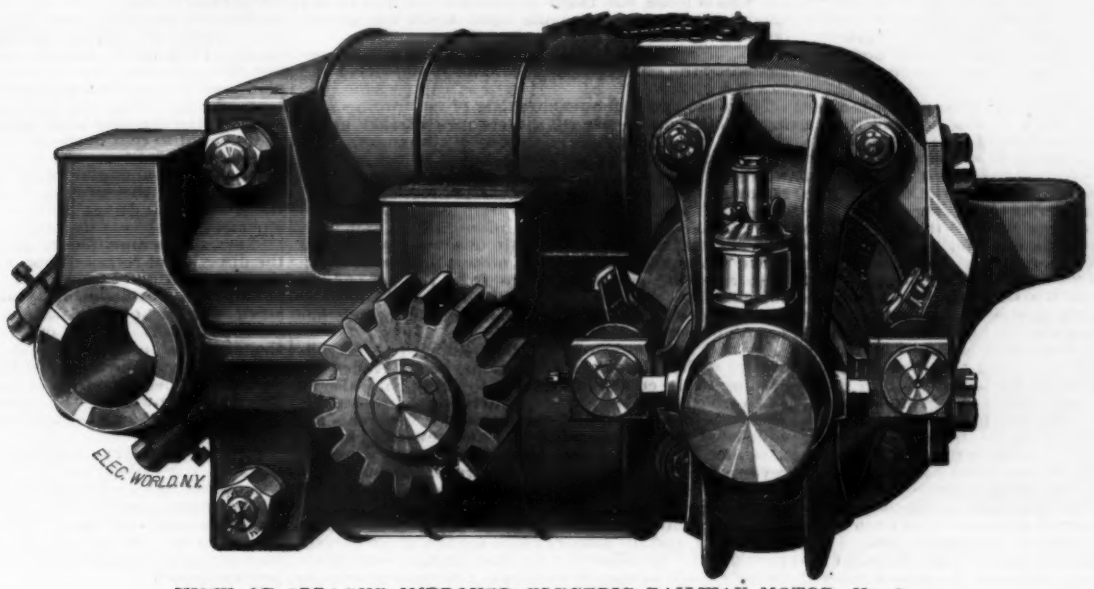
space seems to be taken. On this car must be mounted one or more motors weighing anywhere from 1,000 to 3,000 pounds, whose normal speed must be reduced ten or twelve times, while perfect freedom of axle movement and resilience of car springs must be preserved, as with this additional weight and system of gearing the car is driven over irregular tracks, around sharp curves, and up heavy grades. It must, moreover, be handled by ignorant men, be reliable, not apt to get out of order, and have a reasonable depreciation, although exposed to the worst abuse of any class of machinery.

Almost every mechanical application which can be devised has been proposed or used for accomplishing the necessary reduction of speed, and many methods of supporting motors have been put into practice. These last may be divided broadly into two classes; in the first the motor is carried on the car body, either underneath it, as in most European experiments, or in the interior or on the end of the car, as in some of the earlier American work, the motion of the motor being transmitted to the wheels by various flexible connections, such as belts, flat or link, chains or spiral cords, often with some means of tightening them or of taking up the varying slack. This method is most objectionable, as is evident, for all regular street car work. If the motor is attached to the car body special framing is necessary, and if attached to the under side it is more or less inaccessible. When placed within the car it occupies valuable space as well as changes the car construction, and when at the end entirely destroys the balance of the car. Moreover, the transmission of any amount of power by chains or belts under the strained conditions of car service is utterly unreliable, and makes it practically impossible to drive both axles independently, and only by a coupling chain or connecting rod.

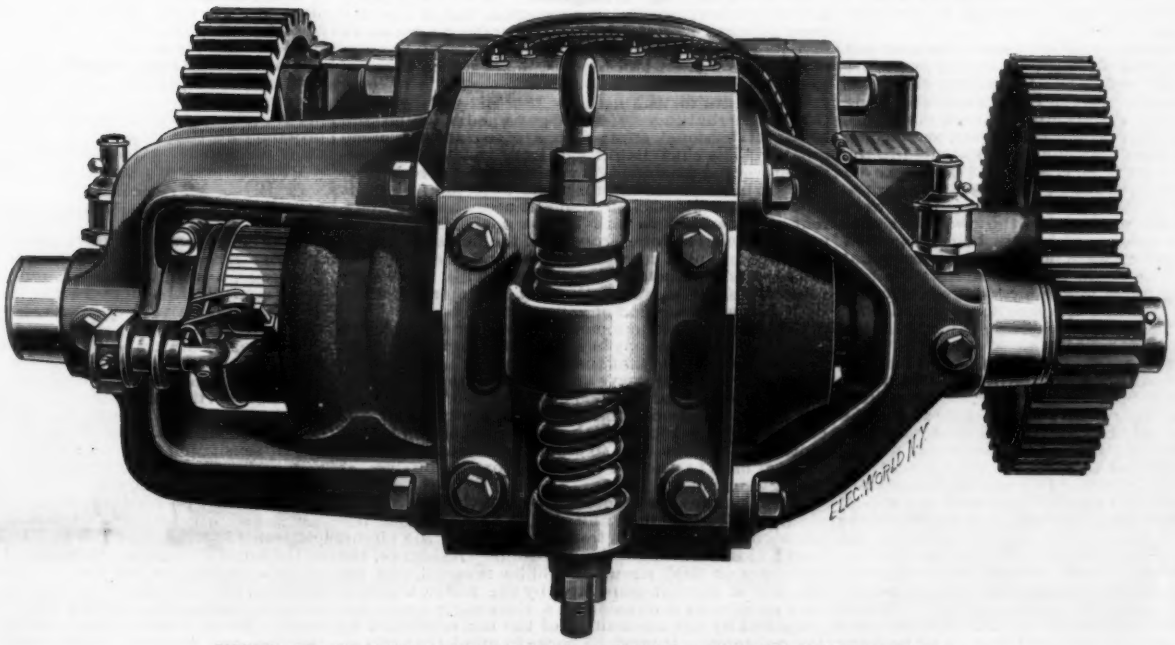
In the second class the motor or motors are supported on an axle frame, and connection is made by chains, belts, ropes, gears, or worms. In some of the earlier work the axles were mounted on a rigid frame upon which the car body rested on springs. The wheels



VIEW OF SPRAGUE IMPROVED ELECTRIC RAILWAY MOTOR—No. 1.



VIEW OF SPRAGUE IMPROVED ELECTRIC RAILWAY MOTOR—No. 2.



VIEW OF SPRAGUE IMPROVED ELECTRIC RAILWAY MOTOR—No. 3.

were connected by side rods, a motor and countershaft were carried in the middle space between the axles, and connected by some form of gearing to one of them. In this method the freedom of axles which is so desirable in street car work was entirely destroyed, and independent driving of the axles lost. Another practice under this general method is to carry a frame on the axle inside the wheels, to set the motor on this frame, and then to gear it by some method to one of the axles, connecting with the other if necessary by side bars or chains; similar objections can be urged against this practice. Conical disks and chains, friction gearing, belts and pulleys, have all been used with more or less trouble and have been generally abandoned. Another practice has been to carry the motor on a frame inside the axle, and to drive with worm gearing; this method has not yet had that hard experience which will warrant any special report in its favor.

In the early stages of this work, I was forcibly impressed with the advisability of fully recognizing the existing conditions of street car and track work, and devised a system of mounting and gearing which, while requiring us to meet extraordinary demands, has proved so successful as to be generally followed. One of the great objections which has been met with in applying motors, whether steam, electrical, or of any other character, to the propulsion of street cars, has been the difficulty of getting sufficient track adhesion to operate the car under all conditions of track, loads, and grades, an objection so important that it is manifest that no application of a motor system can be fully successful unless the entire weight of the car and its contents is made available for traction.

One of the manifest reasons is, of course, the slippery character of the track under many conditions. Another thing should also be noted, which is that it is almost impossible in practice to cast all wheels of exactly the same circumference, or at least so that the paths described by the line of contact shall be the same. Moreover, on curves the wheels are all traveling over paths of different lengths. Theoretically the wheels should be independently driven, but since this is not possible it follows that the next best thing is to drive each pair of wheels independently. It is a fact which admits of no dispute that there are conditions of track which do not permit of a car being driven from one pair of wheels only, and this difficulty is often augmented by the fact that if one pair of wheels only is used they will sometimes be leading, sometimes following; on heavy grades, with one platform reserved for the driver, there is a very serious displacement of the center of gravity, and there may be very much more weight upon one pair of wheels than on the other, thus altering the relative adhesion.

Independent driving and positive gearing became cardinal principles, and then it was evident that a yielding and preferably cushioned support was essential. To these ends one motor is centered upon each axle, and to allow the required freedom of motion, and at the same time to preserve perfect parallelism in the meshing of the gears, and also for taking part of the weight of the motor off the body of the axle and to throw it on to the journals, one end of the motor is supported by double compression springs, playing upon a loosely supported bolt, which is supported from a cross girder in the bottom of the car or on cross beams supported directly on the side framing of the truck or on equalizing bars carried by the axle boxes.

The motors are then, so to speak, weighed or flexibly supported from the car body, and the motion of the armatures is transmitted to the axles through intermediate gearing of compact form and great strength, so that whenever the axles are in motion there is a spring touch of the pinions upon the gears. Barring friction, a single pound pressure exerted in either direction would lift or depress the motor a slight amount, and no matter how sudden the strain, whether because of a variation of load or speed, or a reversal of direction of rotation, the motor yields to it so as to make the pressure on the gears a progressive one. The motors can be carried in the middle space between the axles, or external to them, although the former method is preferable. By detaching the flexible suspension, the motors can be swung around the axle or allowed to hang from it over a pit where they can be carefully inspected or cleaned.

We have had many forms of motors, the first put into use being designed especially for compactness and for high speed on levels. In this motor, which has four cores horizontally disposed, the armature being parallel to the axis of the machine and with bearings in the keepers, the gear reduction is about six to one, and the driving is from both ends to gear bolted to the axle. These gears differ in character. One is keyed and bolted directly on to the axle and is a fixture; the other is composed of four parts, two being inner webs which are keyed on to the axle, the two outer ones forming the gear section, which are bolted together, and have corresponding webs projecting inwardly and fitting snugly both on the outer edge and on the face of the webs. The outer and inner webs are clamped together by bolts passing through them which work in curved slots. These then constitute adjustable split gears.

The pinions on the armature shaft are set so that the one is half a tooth in advance of the other. Ordinarily it would be a very difficult matter to get the splines cut on both the armature shaft and the axle and in the pinions and gears so that they would mesh smoothly in running forward and backward, and it was for the purpose of getting rid of this trouble that the adjustable split gear was designed. It is now only necessary to key the two pinions, one fixed gear, and the web of the other gear in position, without any regard to the meshings. The motor is then swung into position, the hangers made to engage the axle, the caps are put on, and the motor being moved forward and backward two or three times while the bolts of the adjustable gear are slack, this gear will assume a correct position. The bolts are then tightened up, and there is thus a nest of double pinions and double gears all meshing with absolute precision, no matter whether the motor runs backward or forward. The method of the mounting produces a concentric motion around the axle, and by this means the driving and the driven axle are maintained absolutely parallel in two planes under all circumstances. For high speed and heavy work this method is very efficient.

In using this same form of motor for heavy work, where it is necessary to reduce the gearing about 12 to 1, a change is made as follows: On one end of the machine a conical ended and flanged stationary stud is fitted into the keeper; this carries an intermediate gear and pinion on a common shank, the gear being of cast iron or fiber accurately cut and receiving motion from a pinion on the end of the armature shaft; the intermediate pinion is cast and projects into and engages the teeth on any internal split gear keyed to the axle, this last being cast to a carefully planed pattern. In this way an intermediate transmission was effected, with only about 12 inches between outside centers, and the moments on the stud being opposite and equal, there is little strain on the stud.

In the later type of heavy motors, which is a revival of a form I early devised for this work, the ⊃-shaped magnet has been adopted with a single commutator and a complete wrought iron magnetic circuit. The intermediate transmission is by means of a countershaft carried in dust-proof bearings in iron brackets, which likewise support the keeper of the machine and center on the axle. The impossible in this machine will be realized. It will be practically anhydrous and waterproof. Being in part supported flexibly on a frame carried by equalizing bars yieldingly supported on axle boxes, the resilience of the car springs that support the car body will be undisturbed.

The ratio of reduction in gearing is of course dependent upon the size of the motor and the work which it is called upon to do. The maximum allowed peripheral speed of the armature and the speed of the car are also determining elements.

A convenient formula is as follows:

$$R = \frac{f D}{88\, m\, d}$$

when

R is the ratio of reduction,
m, miles per hour,
d, diameter of armature in inches,
f, maximum peripheral velocity of armature per minute,
D, diameter of car wheel in inches.

In determining the method of controlling the motors on a car, it is necessary to consider not only the question of construction of machinery and repairs and depreciation, but the question of efficiency, certainty, and facility of control and the economy of operation, and this is made the more imperative because of the new demands which are made upon street car service both as regards load and speed of running.

It is, of course, essential that both motors are controlled by the same apparatus and also from either end of a car.

There are two different methods of controlling now in use. One makes use of a resistance carried under the car, which is gradually cut out of the circuit. This is Siemens' method. It may be used in conjunction with a switch to make a change in the number or arrangement of the field coils. This method I used experimentally on the elevated railroad in 1886. Another method is to use three or more field coils in parallel circuits, cutting into circuit one, two, or three of them. In both methods series motors are used. Both use a reversing switch separate from the controlling switch. One practice has been to make the brake handle operate the resistance—a method which has serious objections.

My own method is to wind the field with three coils of wire with different cross sections, being graded according to the current they have to carry, and also so as to give a good progressive variation of resistance. The ends of the coils and the armature terminals are connected to a single commuting and reversing switch at either end of the car, which, by a single direct or reverse movement, sends the current through the armature in one direction or the other, and progressively commutates the field coils from three in series to three in parallel with each other, varies their resistance from 9 to 1, and the ampere turns for any given current from 3 to 1. In order to cut either machine completely out of circuit, in case of accident, a three-way cut-out box is introduced into circuit.

The commutating arrangement of fields requires somewhat more careful construction, but it has the great advantage of starting and operating a car on all save its maximum speed and loads with much less current than a motor controlled by a resistance external to the field, for the simple reason that the affected spires of wire on the field on the first step is about three times that in a resistance-governed machine, and hence its torsional effort with a given current much greater. The chief liability of trouble with the resistance-governed machine is burning out of the resistance box. It has another most serious objection, which is that with fixed loads and grades it uses the same current at low speeds as with higher ones. In the commutated field machine, crossing of the fields may occur unless care is used in construction and they are protected from inductive discharges. This is entirely practicable. It is, unquestionably, the more effective and economical method of government.

Let us consider for a moment how a car or train propelled by electricity may be stopped through its agency. It is quite evident that the brake shoes may be energized in a variety of ways and be drawn to the wheels, or that mechanical methods may be used depending for their operation upon electrical contrivances, the current being taken from the line or generated by the motor. We do not need to consider these methods, but turn at once to the use of the motors themselves as acting agents.

When simple series motors are used, their particular manipulation is limited and simple. One or both terminals must be broken from the line, and the circuit being closed through the controlling resistance, the armature or field circuit should be reversed, and the amount of current generated by the motor, which is now running as a dynamo at a slackening speed and propelled by the momentum of the car, controlled by the resistance. It must be borne in mind that this reversal of contacts is necessary because the direction of the motion of the armature being unchanged, its E. M. F. with the residual field is nominal and weakening, and it can only be increased by sending a current in the same direction as at first. If the field is commutated, then the circuit can be closed on a fixed resistance, the switch reversed and the fields changed as desired. When in this position, if line connection is made, the machine will be reversed. With shunt machines, or cumulative machines with means for cutting out the series coil, a very beautiful method of braking is available, which depends upon the fact that the motor generates its own E. M. F., and that is dependent upon the speed of the rotation of armature and the strength of the field. As already pointed out, when a shunt machine is used, to lessen the work which it is doing at any given speed, it is necessary to increase the strength of the field, which raises the counter or motor electromotive force. It is evident that when the motor is running at a given speed, if the field is still further increased, we reach a point when the line E. M. F. and that of the motor is exactly equal, and then the slightest change in the strength of the field or in the speed of the motor will make the motor either take current from the line or raise its E.M.F. above that of the line, and give current to it in the latter case, using up the energy of the train, preventing it on a down grade from accelerating its speed, and even slowing it down, if the field is sufficiently increased. On account of the limit of this increase of field strength, it finally becomes necessary to close the armature on a local circuit. It is not out of reason to say that the resistance then used might, on a car frequently started and stopped, be used to heat a car.

This method of braking is one of the most effective possible. By it fixed skidding and flat wheels are impossibilities. When desired, the braking can be made so sudden as to cause the wheels to have a slight continuous skidding rotation, not such a skidding as is caused when a brake shoe is set too hard, but a slip which is just sufficient to relieve the armature when the strain on it reaches the point determined by the rail adhesion. The wheels will turn till they come to a dead stop.

How important this method of braking may become may be seen by considering the fact that on the elevated roads in New York, of the total energy expended about 59 per cent. is used in getting trains under way, 24 per cent. for lifting on the grades, and only 17 per cent. for traction, and that by a proper arrangement of track circuit there would be a difference of 35 to 40 per cent. in the net power required between two systems, one using and the other not using this system of braking. In a double track road, properly joined together, the entire electrical system is bonded together in a more perfect manner than would be possible by any mechanical means. With all trains running on down grades, and stopping generating current, there would be a system of movable generators re-enforcing the supply of the main stations at several points on the line, thus reducing the size and cost of the generating plant and the conductors needed by about 35 or 40 per cent. Instead of having a net loss of double conversion to offset, the capacity of the generating plant would be about equal to that of the net power now developed as the average duty on the line, which is about 40 per cent. of the total engine capacity.

In reversing the circuits of series motor, so long as the armature is driven in the original direction by the movement of the car its braking action is cumulative, and it makes a much more powerful effort to reverse the direction of rotation than when standing still with the same setting of the switch. This may be compared to the extra pressure on a steam cylinder in compressing a full cylinder of steam with the ports closed.

I should have pointed out that it is possible to use the energy of a car propelled by storage battery to partly recharge the batteries when stopping, although this has not been done yet, in any extended way. Some idea of the growth of the application of electricity to railway service may be gathered from the following facts:

Prior to February of last year there were only a few small electric railways in the country; in that month was opened the Union Richmond Passenger Railway, whose normal equipment, soon after completed, was forty cars operated upon twelve miles of track, and on grades and with curves before that time considered insurmountable with ordinary street car service by self-propelled cars.

By the first of July next, there will be in operation or under contract for construction in the United States alone not less than 150 electric railways, a very large majority of which will be by the underneath contact single trolley wire system.

It has already been most forcibly demonstrated that with proper care the cost of motive power by the direct consumers of the supply is not over one half as much per car mile as when horses are employed. It is hardly necessary at this late date to touch upon the many other advantages which this system has to commend it over the present method of traction.

SILVER PRINTS ON ROUGH DRAWING PAPER.

SOME photographs I have lately printed on rough drawing paper, by a simple process which I practiced years ago, having been much admired by those who have seen them, and as I have had many inquiries concerning the *modus operandi*, I append the following particulars:

Cut rough drawing paper into convenient sizes, and coat each piece on one side, by floating, with a warm solution of gelatine, made by dissolving sheet gelatine in the proportion of 4 grains to 1 ounce of water and 5 grains of chloride of sodium. After drying spontaneously, the paper is ready for use at any future time.

The sensitizing is a very simple and easy process, and a sheet may be got ready for the printing frame within a quarter of an hour. Fasten the paper by pins at two corners, with the prepared side uppermost, on a board slightly smaller each way than the sheet, and place this in a sloping position. Pour a small quantity of the sensitizer into a small vessel, such as a wineglass or an egg-cup, and, with a brush well filled with this solution, coat the paper by applying it in transverse strokes, commencing at the top, and working downward. When coated, bring the paper to a vertical position, and suspend it by one corner, attaching a fragment of dry blotting paper to the lower corner to absorb the superfluous liquid. The drying of the paper may be expedited by holding it in front of an ordinary fire. The printing should be carried considerably beyond the strength ultimately required, as much is lost in toning and fixing.

To make the sensitizing solution, dissolve 60 grains of nitrate of silver in 1 ounce of distilled water, and add carefully drop by drop, and with shaking, strong

liquor ammoniæ, until the solution, which at first becomes muddy, just clears again. If this stage is accidentally passed, add a trifle more silver.

It is obvious that a brush set in metal would be unfit for this process, but one which is thoroughly efficient and presents the advantage of being renewable for each operation is that known as a Buckle brush (from the name of its inventor), made by taking a piece of glass tube say eight inches long and half an inch in diameter, and drawing into one end of it, either with a piece of silver wire bent to form a hook, and long enough to pass through the tube, or with a piece of string, a tuft of cotton wool, the fibers of which have been drawn out lengthwise, the wire or string passing round the middle. When the cotton wool is partially drawn into the tube, where it should fit tightly, it may be pulled into shape, and will be found an excellent tool for the purpose.

I have found a toning bath made with chloride of gold and bicarbonate of soda best suited for this paper, and with this, if the toning is carried far enough and the negative is a good one, black tones, rivaling platinum, may be obtained.

This mode of printing is well adapted to bold and vigorous subjects, and, as the paper does not curl, the pictures may be printed with deep white margins, rendering mounting unnecessary; the beauty of the photograph being, at the same time, much enhanced by the coarseness of the texture of the white paper.—*J. H. Biggs, in Photo. News.*

JENNER AND VACCINATION.

SINCE we are in the period of centenaries to be celebrated, we shall, in a few years, be able to think of that of Jenner and of his celebrated discovery of vaccination. England will not care to leave to other countries the duty of celebrating the memory of one of her most glorious children, of one of those whose memory will live beyond the ages, and the whole world will, without reservation, participate in this festival of one of the noblest conquests of medicine. The country of Jenner, however, is one of those in which the anti-vaccination league has made most converts, or, at least, in which vaccination is still meeting most opposition. We now no longer count the struggles of the sanitary authorities of various counties and villages with the vaccinating physician. The very palpable, very demonstrative facts are there, nevertheless, to prove this practice to be well founded; but there is still a goodly number of contrary persons who boast of a few accidents caused by inoculations in order to fight the generalization of a measure which during the past century has saved thousands of lives.

In countries in which vaccination has been rendered obligatory, mortality from the smallpox has become, if not an unknown, at least a very exceptional thing, and we have but to compare the statistics of Prussia, where vaccination is obligatory, and of France, where vaccination is nevertheless generally accepted, to see the results. The immunity against smallpox that vaccination furnishes is not of eternal duration, but even ceases in quite a short time, and hence the very wise advice to have one's self revaccinated, on an average, every ten or fifteen years, or sooner when an epidemic is threatened. Vaccination is everywhere put within the reach of all, with absolute freedom from expense; but, no matter, unconcern is stronger than wise advice, and, every year, in various parts of the territory, in large cities, we see epidemics of varying severity reported. Tables of mortality every year show a relatively high figure of deaths from smallpox, while the disease should long ago have disappeared, and be but a sad remembrance, like the great scourges of past ages.

I permit myself to anticipate the centenary of Jenner a little, and to devote a few lines to this distinguished physician. The idea occurred to me on rummaging through the rich collection of prints belonging to Mr. G. Tissandier, the editor, who is the possessor of a series of very pretty caricatures on vaccination published in France about 1880 (Figs. 1 and 2) and of a wonderful portrait of Jenner engraved in mezzotinto (Fig. 3). It struck me that my readers might find something of interest in the publication of these curious pictures, and might be pleased to see these evidences of the sharp struggle that the partisans of vaccination were obliged to maintain in order to cause the propagation of the great discovery of the learned Englishman to triumph.

Edward Jenner was born May 17, 1749. He was the youngest child of a rector of Rockhampton, vicar of Berkeley, Gloucestershire. Brought up by his brothers on the demise of his father, who died suddenly, he early had a taste for natural history. He began the study of surgery with Ludlow at Sudbury, and afterward went to London, where he became the student and friend of the celebrated Hunter.

The love of family, says his friend Valentine, our compatriot, made him renounce Hunter's finest offers, and he returned to his native place, Berkeley, in order to practice medicine there. While administering to the sick, Jenner did not neglect natural history, especially ornithology, and his labors in this branch of the science soon opened the doors of the Royal Society of London to him. It was about 1776 that he began his researches upon cowpox, and these required twenty years of patient effort to determine the intimate ties that connected this virulent eruption with variolic immunity. The thing now appears very simple. It was in fact a popular dictum that shepherds and farmers who accidentally took cowpox from their animals were proof against smallpox. Jenner made a close observation of these spontaneous and accidental occurrences, and, later on, in support of the truth of this dictum, related the following story: The Duchess of Cleveland, a very pretty woman and a favorite of Charles II., on being rallied by some ladies of the court to the effect that she might soon deplore the loss of her beauty through getting the smallpox, which was making ravages in London, answered them that she had no fear of it, seeing that in her country she had had the cowpox, which rendered her proof against it. It was on the 14th of May, 1796, a memorable date, that Jenner, courageous from his observations, dared to perform the first official vaccination.

The person who furnished the vaccine matter was a peasant girl who had been inoculated in the hand with the cowpox, and the subject was an eight year old boy, who had from it a beautiful vaccine eruption, and upon whom two inoculations of variola were tried without success. In 1798, Jenner published his first work: "Inquiry on the Causes and Effects of the Variolæ Vaccinæ." This work contains four beautiful colored plates representing vaccinal pustules in various phases of evolution.

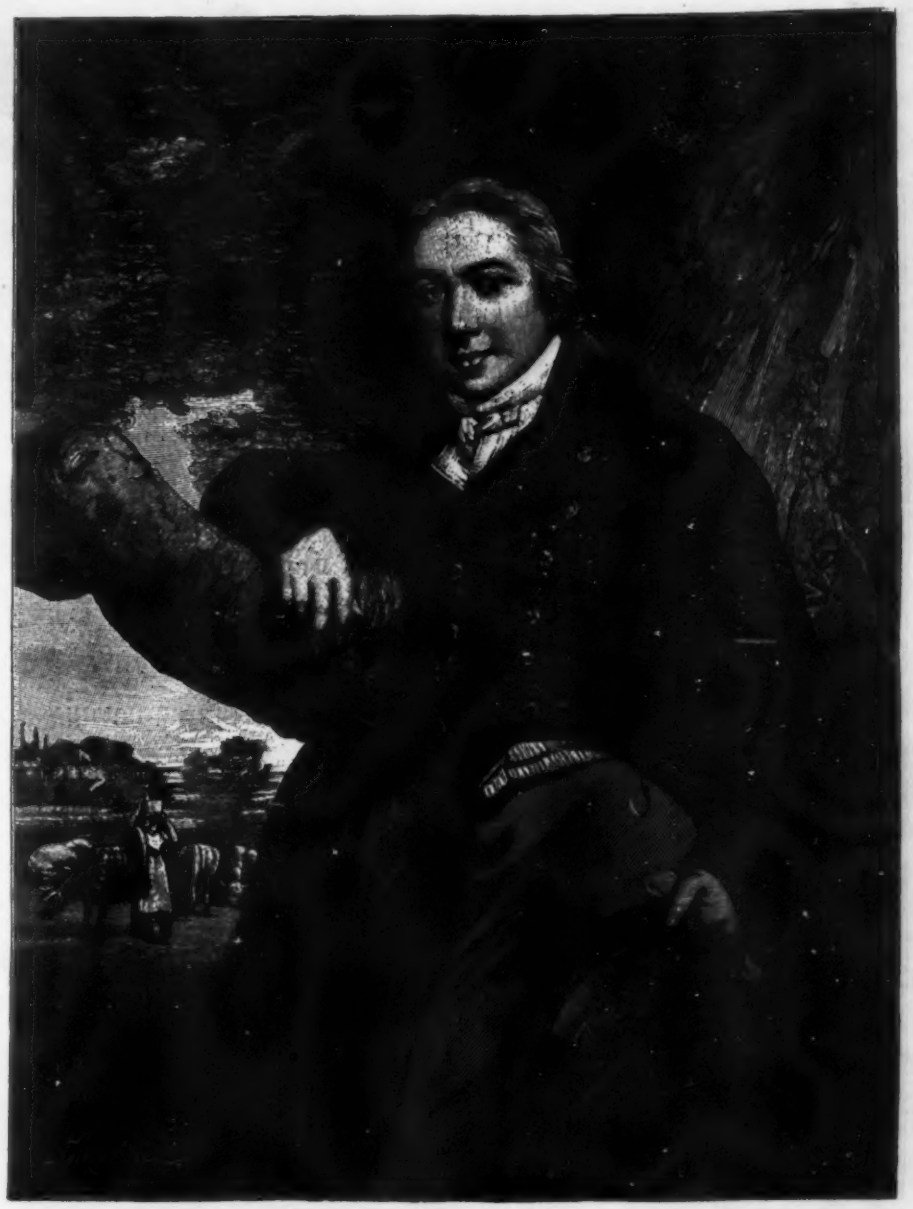


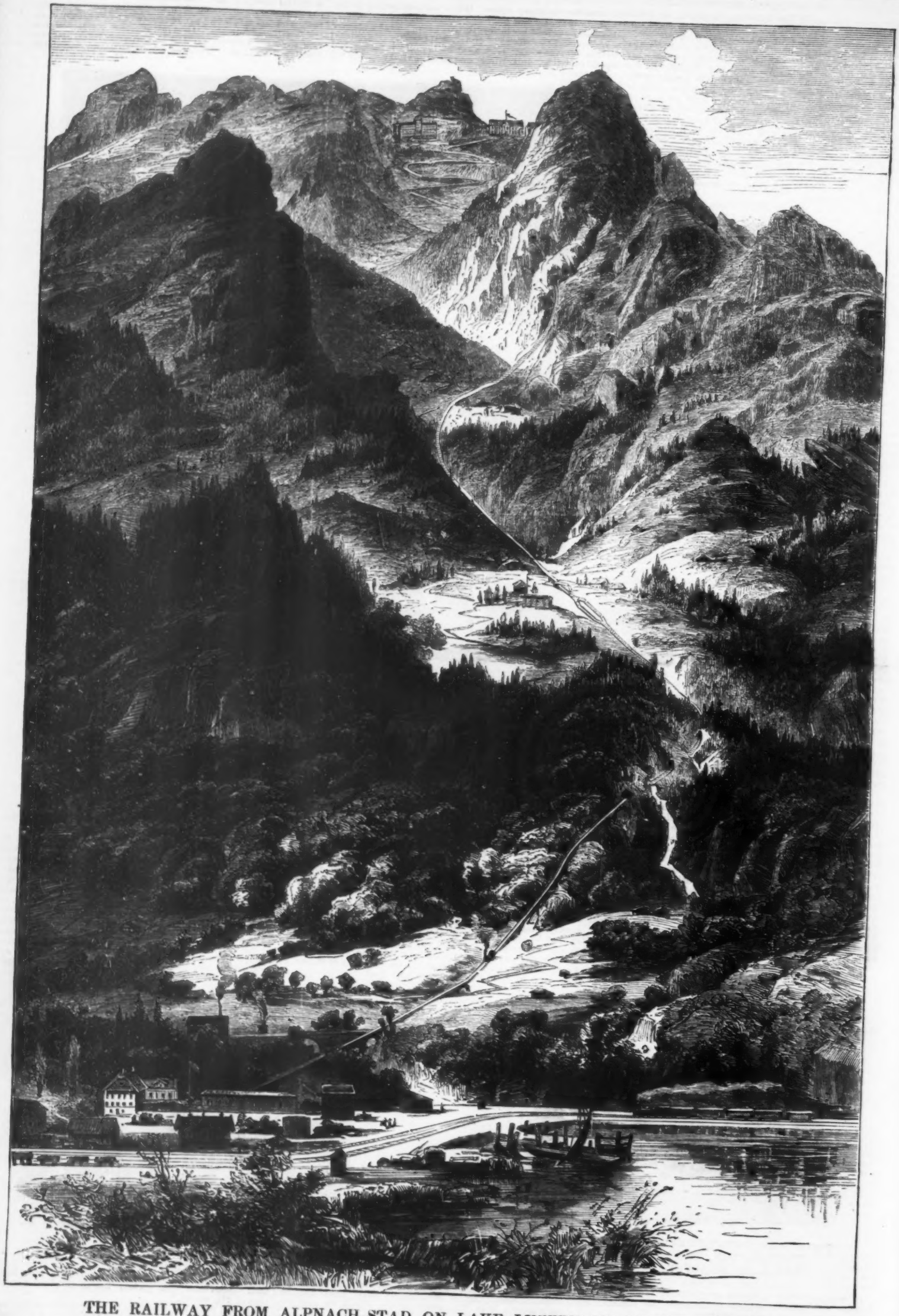
FIG. 3.—DR. EDWARD JENNER.

Jenner's discovery spread rapidly. As far back as 1800, vaccination was tried in France, and the results were such that in 1801 the physicians and surgeons of the English navy offered their compatriot a great commemorative medal. Testimonials of gratitude were soon forthcoming. In 1802, the English parliament voted him a national award of 10,000 pounds, and, in 1807, added to it a further sum of 20,000 pounds, while Lord Chatham, a son of the great statesman, consecrated the glory of Jenner in these words: "The chamber may vote to Dr. Jenner such a reward as it shall judge proper; he has already received the unanimous approval of the chamber—a very precious approval, since it is the result of the greatest or one of the most important discoveries that society has made since the creation of the world."

Loaded with honors, a member of all the societies of the scientific world, Jenner had the honor of looking on at the triumph of his ideas and at the universal propa-

FIG. 1.—OLD CARICATURE ENTITLED, "DEATH OF VACCINATION IN PREMATURELY DROPPING HER LAST MONSTER."

FIG. 2.—CARICATURE ENTITLED, "THE ORIGIN OF VACCINATION."



THE RAILWAY FROM ALPNACH-STAD, ON LAKE LUZERN, UP MOUNT PILATUS.

gation of his discovery. He continued to reside at Berkeley, surrounded by his family, and pursuing his studies. It was there that he died in 1825. An attack of apoplexy came upon him in his study, and carried him off in a few hours.

Vaccination, as I have said, has saved thousands of lives, but that is not all. Jenner's discovery was the starting point for the modern biological researches upon virulent diseases. The word vaccination has become a generic term, which is applied to the attenuated viruses of this or that disease. The brilliant results obtained by Mr. Pasteur are well known. At present, cattle are being successfully vaccinated against charbon and pleuro-pneumonia; we have a means of combating rabies, and we shall perhaps soon have a means of checking diphtheria and other virulent diseases. The progress made for a few years past in all countries by the study of bacteriology permits us to hope without temerity for the solution, in a near future, of the problem of the prophylaxis of several of these affections.

We have nothing to envy in the glory of England. Although, in the last century, she had a Jenner, we have Pasteur and his pupils, who will leave their names to posterity.—*Dr. A. Cartaz, in La Nature.*

THE NEW PILATUS RAILWAY.

THE incredible has been accomplished. The locomotive climbs from Alpnach-stad up Pilatus, which rises into the air like a Titan. For two winters the road has withstood the thundering slides, the rushing waters, and the fierce winds, and now that it has been opened hundreds of passengers are carried daily from the romantic lake through the wilderness of mountain heights to the pure air of the ever-visible peak. One standing on the Palais Quay at Luzern and looking up at Pilatus rising in its proud majesty like a prince commanding the entire region, can scarcely realize that in less than five hours a visit can be made to the summit which promises such a wonderful view. There is no need to ask about the weather; if the mountain has a cap of mist, the weather is good; if he has a neck-band, one may venture; but if he has a sword, it will rain. These are the mountain's never-failing weather signals.

Formerly only bold adventurers climbed this mountain, which Herwegh called a beautiful "Statue of Liberty;" and then, when easy paths were made to the top, and finally a hotel was placed on the saddle between the two highest peaks, the number of visitors was increased, and gradually the idea of this gigantic undertaking, building a railroad, took shape. Its construction required hardly a year, and now, when looking at the wild, lonely giant, a little white column of smoke rising against the dizzy wall of rocks is discerned. A little black point comes down the mountain with it, suddenly it disappears, to appear again lower down, and gradually, by close watching, the line followed by the column of smoke and the little black point is discovered. That is the Pilatus railway, which descends the southeastern slope to Alpnach.

But is not such a journey dangerous? Can this vehicle be trusted, and will the view pay for the trouble and anxiety?

We have had many proofs that technology of to-day works on heights and in the depths as safely as on level ground, but this great work carried out so successfully, energetically, and safely by the builders, Messrs. Ed. Gujer-Freuler and Ed. Locker, of Zurich, is a real triumph of science. There is nothing alarming in the ascent, although the grade reaches 48 per cent.

In the beautiful green "Alpnach-stad," on the banks of the "Alpnacher See," shaded by mountains, where the steamer makes its last stop and the Brunig road starts, forming the connecting line with Luzern, stands the station of the Pilatus railroad, within an hour's journey of Luzern by boat and cars.

Directly from the station the road starts up a steep grade, soon passes through a beautiful wood, then over two little viaducts and through three short tunnels; and then, after a sharp turn to the west, it climbs the Aemsigen Alp, from which we have a fine picture of the high Alps. Here there is a switch station, and generally the stop is long enough to allow of leaving the cars and enjoying the view, through the openings in the woods, of the glistening lake, the dusky Bürgenstock, and the distant mountains. Soon after leaving the Aemsigen Alp the characteristics of the high peaks show themselves, the woods are left behind, and solitary, weather-beaten firs stand out from confused masses of rocks, from which project single blocks covered with the beautiful Alpen flora, which is also left behind as the road suddenly enters a basin of rocks above the Matt-Alp, from which the high peaks rise almost perpendicularly—to the left, Matthorn, Tomlishorn, and Oberhaupt; to the right, the highest point of the mountains, the Esel, with its precipitous wall of rocks. In the winter the elements expend their force here, the slides thunder, the water roars, the rocks are torn asunder, and the mist makes mysterious pictures, but when the mountain is free from snow the most profound stillness reigns. To the left, along the Matthorn leads a path for horses and pedestrians, which the road has already crossed several times, but which now takes a very different course. The railroad creeps up the Esel wall and through four little tunnels, and a look back into the basin below shows the fearful height attained. A few minutes more, and the quietly and slowly climbing engine draws into the station on the top of the mountain. The journey has lasted hardly an hour and a half. The descent requires about the same length of time. A pedestrian with good lungs makes it in about four hours.

On stepping from the station we stand before the Hotel Bellevue, the old hotel, and a short distance off, on a similar height, stands the well-arranged new hotel, the "Pilatus-Kulm." Here we find the necessary refreshment as good as in the valley, and then we climb up to the summit of the Esel, which is about 130 feet higher than the hotel. An easy, well-made path protected by a balustrade leads around the cone to the top (about 6,881 feet above the level of the sea), on which a high signaling pole stands. From here there is a magnificent view which well repays the trouble and fatigue caused by the journey.

It is a most beautiful panorama. Directly at our feet lies beautiful Luzern, and beyond this the glorious green landscape stretching out to the Jura and the Black Forest. How many villages, little cities, great cities! Farther to the right, at the foot of the Pilatus, we see the romantic Vierwaldstattsee, and rising from its other bank, that friend of all the world, the incomparable Rigi, directly opposite the majestic Sentis, and finally the whole circle of Alps in its proud, still, sunflooded beauty. These Titans seem near enough to be touched, one peak follows the other, each higher and more imposing. It is a wonderful panorama, and any one who has seen it once will always desire to see it again.—*Illustrirte Zeitung.*

THE HOTELS AND RAILWAY STATION AT THE SUMMIT OF MOUNT PILATUS.

THE CONSTITUTION OF CELESTIAL SPACE.

M. G. A. HIRN has recently published an able and interesting work, entitled "Constitution de l'Espace Celeste," in which, says *Nature*, he inquires into the nature of the medium or agent which establishes and carries on the relationships of the celestial bodies. For all of these, from the most enormous sun to the most infinitesimal meteorite, are in constant relationship to each other, continually attracting each other, continually radiating and receiving light and heat. Newton long ago regarded it as the greatest of absurdities to imagine that "one body might act upon another at a distance, through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another. Gravity," he added, "must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers."

This question, left unsolved by Newton, Hirn answers as follows: "The thorough analysis of the most diverse facts revealed to us by science to-day allows us to reply to the first question by the most absolute negation. That which fills space and which establishes relations between the celestial bodies is not diffuse matter."

That "ponderable matter in the state of a diffuse gas" does not fill interplanetary and interstellar space M. Hirn seeks to prove by inquiring what effect such a medium would have on the various members of the solar system, and particularly upon their movements. Many of his conclusions are exceedingly striking, and if accepted, certainly prove his main proposition given above. Perhaps the most remarkable is that relating to the secular acceleration of the moon. To explain a secular acceleration of 0 5″ in the mean motion of the moon it would be sufficient if 1 kilogramme of gas were distributed over 975,000 cubic kilometers of space; a rarefaction one million times greater than that of a Crookes vacuum of the millionth of an atmosphere. But the effect of the shock of the particles of this rarefied gas against a body like the moon as it moved forward in its orbit would be to raise the gas to a temperature of 38,000° C., and inconceivably attenuated as this interplanetary atmosphere would be, the moon would yet come into contact with 600 kilogrammes of it in each minute of time. On a body like the earth, surrounded by an atmosphere, the inevitable result of this unceasing collision with the interplanetary atmosphere would be the stripping away of the terrestrial atmosphere

layer by layer. Arriving at results of a similar unacceptable character from the consideration of the action of a diffuse interplanetary gas on the other members of the solar system, M. Hirn decides that matter exists only in a sporadic state in space; only in the state of distinct bodies—stars, satellites, meteorites, and the like. It exists in a state of extreme diffusion only in nebulæ, but elsewhere space is perfectly empty, or, at least, whatever remains cannot suffice to explain the relations of stars to stars.

[SCIENCE.]

MAGNETIC STORMS AND THEIR ASTRONOMICAL EFFECTS.

THE earth is sometimes spoken of as a great magnet. Its magnetic condition, however, is not constant, but varies within rather wide limits. Some of the changes are periodic, while others are spasmodic and irregular. The sunspot period appears to be in some way related to the changes in the earth's magnetic condition; for, at the time when the spots are at their maximum in number, the so-called magnetic storms are most frequent and violent. There is a general agreement among meteorologists that the magnetic changes observed upon the earth are in some obscure manner due to the influence of the sun.

In meteorology, as elsewhere, when other explanations are unavailable, resource is found in electricity, especially so if electrical phenomena can be in some manner discovered to be involved; and this happens to be the case in a very great number of phenomena, not as causes, but as effects. Not infrequently it happens that some of the best known laws of electricity are ignored, or are confounded with other laws of other forms of energy. This seems to be precisely the case in this phenomenon.

In his article upon meteorology in the last edition of the "Encyclopædia Britannica," Balfour Stewart says, "We are thus driven to look to the upper regions of the earth's atmosphere as the most probable seat of the solar influence in producing diurnal magnetic changes; and it need hardly be said that the only conceivable cause capable of operating in such regions must be an electric current. Now, we know from our study of the aurora that there are currents in such regions, continuous near the pole, and occasional in lower latitudes." And yet a little further on he argues very properly that more knowledge seems to be needed before we can assert that there are currents of electricity in regions where conduction is impossible.

Now, a current of electricity always implies conduction, and conduction implies molecular contact. We are abundantly able to prove this; for with such vacua as can readily be produced, say the millionth of an atmosphere, not only will electricity not traverse it, but even Crookes' phenomena cease. At the height of one hundred miles, the average free path of the molecules is measured by feet; and this renders it as certain as anything we know in physics, that electrical currents are impossible there, and hence, whatever may be the explanation of the magnetic changes in the earth, they are not due to currents of electricity in those high regions.

Still the earth is a magnet. It has its poles, though these change their position. The bulk of the earth with which we are acquainted is made up of non-magnetic matter, having varying degrees of conductivity; the rocky part being very poor, while the oceans and moist soils are conductors to such a degree as to permit commercial use for telegraphic and other purposes, thus saving the cost of a return conductor. The larger part of the surface of the earth is, then, an electrical conductor. Whenever a conductor of electricity is rotated in a magnetic field, an electrical current is the result; and such current is maintained so long as the rotation is continued, the strength of the current depending upon several variables—the strength of the magnetic field, the degree of conductivity, and the rate of rotation.

That electrical currents are continually traversing the crust of the earth has been established, since the telephone has provided us with an instrument delicate enough for observation, and employed by so many all over the earth.

To be sure, it was known before that earth currents were sometimes present, for upon occasions they were so strong as to interfere with or stop telegraphic communication. Such interruptions were generally coincident with auroral displays, but sometimes occurred in the daytime, when auroral effects could not be seen if they chanced to be present. As these earth currents have been found to be coincident with both magnetic disturbances and with spasmodic solar action—for several observers have noted solar eruptions at times when the magnetometers gave evidence of magnetic changes in the field, and in one or two cases even determining that the rate of transmission of the sun's action was the same as that of light—it follows that the earth acts as if it were rotating in the magnetic field of the sun.

If the sun be considered as a magnet, then its field extends to an indefinite distance in space, and the earth must be rotating in it; and, so far as the earth is a conductor, there should be currents in it; in fact, just what we discover. So far, the electricity is an effect, and not a cause, magnetism being the preceding physical state.

A conductor moving in a magnetic field in such a manner as to have electrical currents generated in it always suffers retardation of its motion, as is illustrated by letting a coin fall between the poles of a strong magnet—a property utilized in modern galvanometers to bring the needle quickly to rest. Such currents are technically known as "Foucault's currents," and the energy they represent is at once transformed into heat in the conductor.

The electricity is but the transient state intermediate between the retarded motion and the rise in temperature.

This series of physical relations—viz., the rotation of a conductor in a magnetic field, the retardation of the motion, the electrical current, and the final transformation into heat of original energy of the mechanical motion—is a well ascertained series of effects, which is universal; and thus it follows that, so far as the earth has currents of electricity set up in it by the sun's action, so far its rotary motion is retarded, and also its temperature is increased, both effects not hitherto recognized, so far as I know. Of course, the retardation of motion is very small indeed, but it must be taking place, and in time will bring the earth to a standstill. What the amount may be there appears to be no way of determining, because there is no way of ascertaining the strength of the earth's currents, nor the earth's resistance, nor the strength of the magnetic field of the sun.

Furthermore, the retardation of other bodies in the solar system may be traced to the same physical conditions instead of frictional resistance of the ether, which has sometimes been hypothecated.

Lastly, if the magnetic condition of the earth varies, it follows that the magnetic field of the earth varies, and all bodies in that field are reacted upon by it. The gases of the atmosphere at high altitudes have free paths comparable with those in Crookes' tubes, and might fairly be expected to exhibit similar phenomena if electrified and in changing magnetic field. Their electrification need not be much of an assumption, when one considers what happens in a thunder shower. Rotating molecules, if conductors of electricity, ought to have Foucault's currents in them when in a magnetic field, and they should therefore be heated. As there is no chance for conduction of the heat, the rate of vibration increases till incandescence is reached. The only way in which the molecule can unload its extra energy is by radiation.

The motions seen in auroras may thus be due to the changes in the magnetic field of the earth instead of to electrical currents circulating in the high air.

A. E. DOLBEAR.

College Hill, Mass., April 23.

SOME one who pretends to know estimates that there are 5 American citizens who are worth $100,000,000 each; 5 worth $50,000,000 each; 10 worth $30,000,000 each; 10 worth $20,000,000 each; 50 worth $10,000,000 each; 100 worth $5,000,000 each; 200 worth $3,000,000 each; 500 worth $1,000,000 each; and 1,000 worth $500,000 each.

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TABLE OF CONTENTS.

PAGE

I. ASTRONOMY.—The Constitution of Celestial Space.—A review of the much vexed problem of ponderable matter in interplanetary and interstellar space, a curious study in theoretical astronomy.. 11333

II. BIOGRAPHY.—Jenner and Vaccination.—Biography of Dr. Edward Jenner, the originator of vaccination, with account of the unfavorable reception his discovery met at the outset.—3 illustrations..... 11331

III. CIVIL ENGINEERING.—The New Pilatus Railway.—A graphic account of the new railroad leading from Lake Lucerne up Mount Pilatus, with the description of the two terminal stations.—2 illustrations..... 11333

Wooden Pavements in Paris.—An interesting letter from the general inspector of bridges, etc., of Paris, giving results with wooden pavements obtained in that city..... 11323

IV. ELECTRICITY.—Some Applications of Electrical Transmission.—By FRANK J. SPRAGUE.—The conclusion of this important Sibley College lecture by the eminent electric engineer, devoted principally to the phases of tramway and railroad work.—5 illustrations..... 11328

Windmill for Producing Electric Light at Cape de la Heve.—An interesting instance of the employment of wind power for generating electric energy, with utilization of accumulators for maintaining a constant current.—6 illustrations..... 11327

On the Security against Disturbance of Ships' Compasses by Electric Lighting Appliances.—By Sir W. THOMSON.—An important essay on a new source of danger to ships in the effect of dynamos, etc., upon the adjustment of compasses..... 11325

V. MATHEMATICS.—Radii of Curvature Geometrically Determined.—By Prof. C. W. MACCORD.—The hyperbola and its radii of curvature considered.—2 illustrations..... 11324

VI. MECHANICAL ENGINEERING.—Tractive Force of Leather Belts on Pulleys.—By SCOTT A. SMITH.—A thoroughly practical paper on this ever-interesting subject, treating of the different factors of efficiency existing in belts..... 11325

VII. METEOROLOGY.—Magnetic Storms and Their Astronomical Effects.—A review of the connection between terrestrial magnetism and sun spots, with reference also to auroras..... 11334

On the Influence of Gas and Water Pipes in Determining the Direction of a Discharge of Lightning.—By HENRY WILDE.—A valuable essay upon protection of buildings from lightning, with an examination of the efficacy of grounding lightning rods on underground pipes..... 11327

VIII. NAVAL ENGINEERING.—The Corrosion and Fouling of Steel and Iron Ships.—By Prof. V. B. LEWES.—The great question of the preservation of iron hulls of sea-going ships discussed, with an account of the various methods which have been tried in order to prevent exfoliation and rust..... 11320

IX. PHOTOGRAPHY.—Silver Prints on Rough Drawing Paper.—An excellent hint for an effective novelty in photographic prints for the production of a more artistic effect..... 11330

X. TECHNOLOGY.—Paget's New Warp Weaving and Knitting Machine.—A description of one of the most ingenious and remarkable novelties of the Paris exposition, with illustrations of the machine and a full account of its manipulation and powers.—3 illustrations..... 11319

Xtux.—Note on a new textile fiber plant..... 11324

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